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May 2007

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How to make 20 million galaxies p. 34

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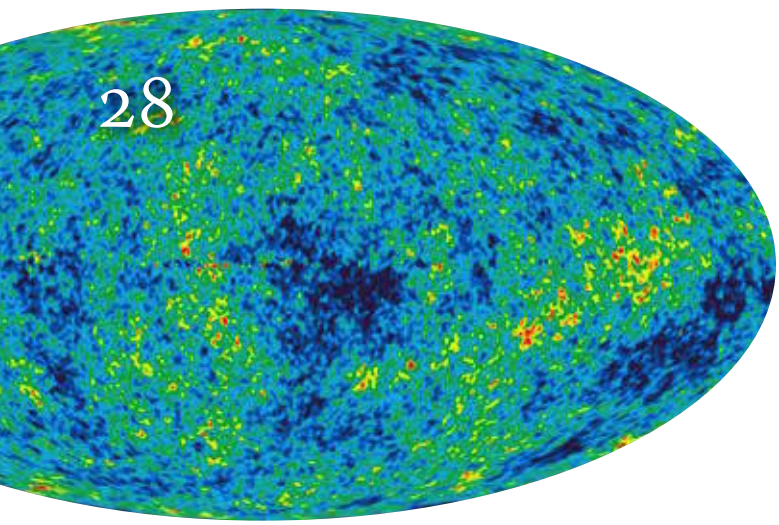

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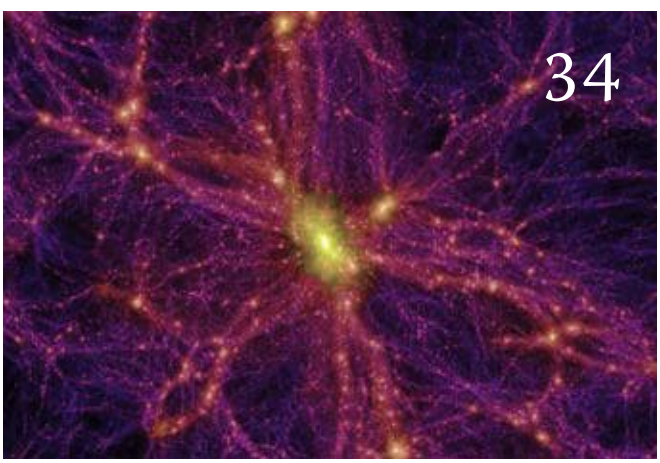

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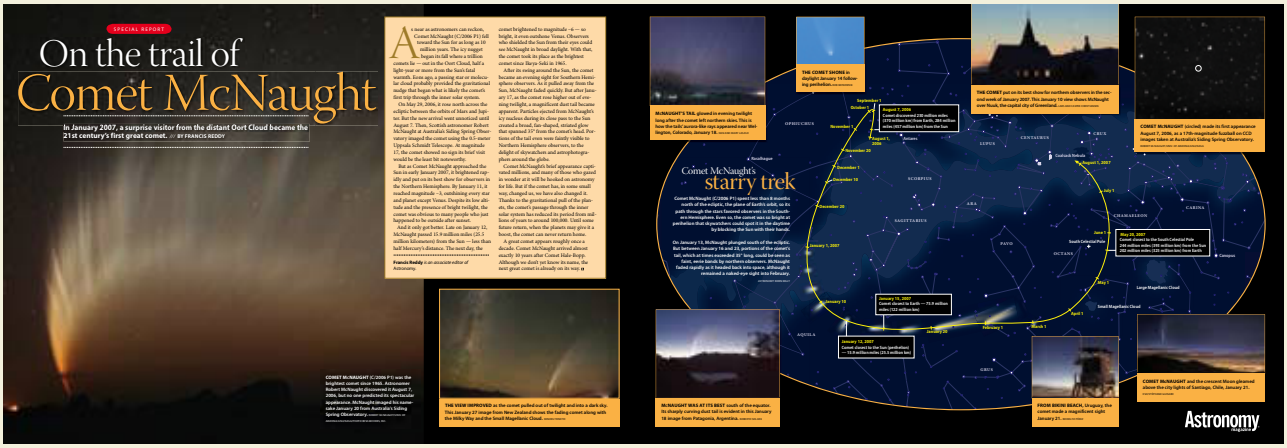
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MARTIN GEORGE

TOM BUSH AND JOHN FOX/ADAM BLOCK/NOAO/AURA/NSF

BY DAVID J. EICHER

The great comet of 2007

Comets are unpredictable creatures.

Sometimes, when you think they're going to be bright, as with 1973's Comet Kohoutek, they fizzle. Other times, they sneak up on you and swing past with almost no warning. This happened in mid-January, when, for a few nights, observers in the Northern Hemisphere caught a glimpse of Comet McNaught (C/2006 P1), which turned out to be the brightest comet in 40 years. The comet put on a show for Southern Hemisphere observers, lasting a few weeks before it faded rapidly. Our next great comet had arrived.

Rob McNaught discovered this comet August 7, 2006, at Siding Spring Observatory in New South Wales, Australia. It was not the perfect comet that all observers who love the sky have been waiting for, however: McNaught swooped in and remained fairly dim, getting very close to the Sun in the sky, and erupted in brightness suddenly, just a short distance from the Sun. No one expected this comet to brighten as explosively as it did, and, for most, it was visible only with difficulty when it did brighten.

In the parking lot at the *Astronomy* magazine offices, for example, our editors observed it low in the sky in bright twilight. We can only imagine what the comet would have been like high in a dark sky, visible for weeks on end.

Comets are magical, almost mystic visitors to our skies. Not only are they beautiful, but they are a rare indication of change in the night sky, which otherwise seems mostly static. No wonder a great comet like McNaught invokes strong feelings within those who see it.

After our few peeks in the north, McNaught slipped into the southern sky and was visible for observers in Australia, South America, and southern Africa. We covered the rapidly evolving event on our web site and featured reader photos you were good enough to send us.

MIKE SALWAY

COMET McNAUGHT was a spectacular sight, as this image, taken January 20 from New South Wales, Australia, shows.

We have commemorated our glimpses of McNaught with a special story, "The Great Comet of 2007," by Senior Editor Rich Talcott, on page 54. In addition, Associate Editor Frank Reddy produced a spectacular bonus poster you'll find in the center of the magazine, titled "On the trail of Comet McNaught," which recalls McNaught and other great comets. Let's hope that the next bright comet stays around a little longer, higher up in a beautiful, dark sky!

David J. Eicher
Editor

Astronomy

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Star birth runs amok

How do you ignite the biggest wave of star formation in the known universe? In the case of the Tarantula Nebula (NGC 2070), you send its host galaxy — the Large Magellanic Cloud (LMC) — on a series of close passes by its big brother, the Milky Way. Such gravitational interactions have triggered star formation throughout the LMC, and the Tarantula stands as the biggest and most spectacular example. The star cluster R136a, seen at the image's top center, is starting to emerge from its natal cocoon. Its brilliant, blue-white stars rank among the most massive known. Thousands of smaller stars are still condensing from the nebula's rich supply of gas and dust. ESA/NASA/ESO/DANNY LACRUE

An amazing sky show

I missed the peak of Geminid activity

December 14 due to cloudy skies; however, I observed just after 4h UT on the 15th at Sleepy Hollow State Park, north of Lansing, Michigan. What I observed was spectacular: A meteor not as bright as Procyon passed in front of the star, creating a "blink" effect. I am 54 and have been an amateur astronomer since my childhood, but I have never seen something like this before.

Just after that, the aurora borealis — which was at first observable only in the far north — expanded and took over the entire northern half of the sky. It then became so bright and intense, it rendered meteor observing useless for the next few hours. It's hard to believe we are near solar minimum!

It was one of my most incredible nights of naked-eye observing in years. **— DENNIS KELLY,** HASLETT, MICHIGAN

THE NORTHERN LIGHTS danced over an EISCAT antenna in Tromso, Norway, December 14. HINRICH BAESEMANN

Can Solar Probe reach 670,000 mph?

In "Can we send a spacecraft to the Sun?" (December 2006), it says Solar Probe will approach the Sun at 670,000 mph. I thought the fastest spacecraft are the Voyagers, which are leaving the solar system at 67,000 mph. Is that a typo or, if it is correct, how does it go that fast? **— BOB BONIECKI,** NAPERVILLE, ILLINOIS

The listed maximum speed of Solar Probe is no typo. The spacecraft travels so fast because the Sun's immense gravity accelerates it as it approaches. Gravity's pull increases as you get closer to any massive object. In fact, if you cut the distance in half, you quadruple the object's gravitational pull. Solar Probe will pass near the Sun. As it does, the Sun's gravity will whip it around so the spacecraft travels away from the Sun.

Acceleration of a spacecraft by the "slingshot" effect is not new. In fact, the Voyager probes used both Jupiter and Saturn's gravitational fields to alter their trajectories and increase their speeds.

Another principle also is at work here. It stretches back to the time of German astronomer Johannes Kepler (1571–1630). The second of his three laws of planetary motion says a planet moves faster as it draws closer to the Sun. If the planet didn't travel faster at that point, the Sun's increased gravity (because the planet lies closer) simply would pull the planet into the Sun. So, for Solar Probe not to fall into the Sun, it must be traveling at the listed speed when it's closest to our daytime star. **— MICHAEL E. BAKICH, SENIOR EDITOR**

Hidden possibilities

Black holes may be composed of dark matter. I have long thought there is actually no physical difference between what we perceive as matter and energy on the smallest cosmic scales. Our computer models are often too limited by what can be or has been measured rather than what can be imagined. **— ADRIAN SHINER,** FARNBOROUGH, ENGLAND

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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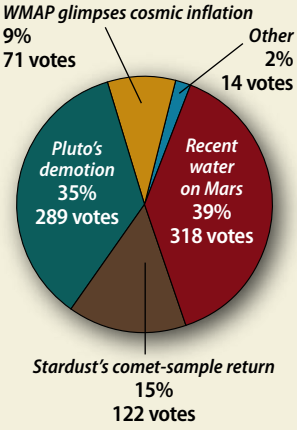

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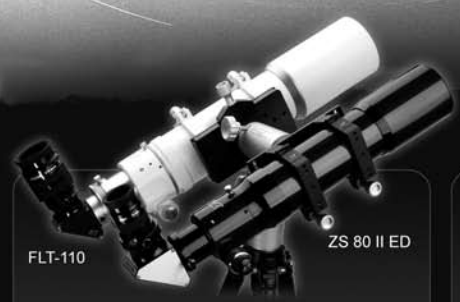

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BY BOB BERMAN

Energy to spare

Wherever we look, we see energy. Yet, most people have no idea what it is. Einstein wrote in 1905 that matter and energy are equivalent. Each can change into the other. A slice of cheddar cheese is nature's way of storing nearly a trillion ergs of energy. If you could convert the cheese instead of melting it, you could light up all the houses in a small city.

Astronomers lump the universe's mass and energy together. Unless there are other universes we don't know about, this total energy inventory is finite — yet we can't use it up. Energy is never lost, never destroyed, never born. Energy changes form, but it never diminishes in the slightest.

Say you drive up a hill, and then let the car coast back down. You started by releasing gasoline's chemical energy, which had been stored in its molecular bonds. Energy that's stored or "waiting to happen" is called potential energy. By making your car move, the fuel's potential energy changes into the energy of motion: kinetic energy. Even light, because it moves, possesses energy, which means it has an equivalent mass. It just doesn't have a "rest mass" because, unlike everything else, it's weirdly compelled to always move. If you could make light stop, it would disappear.

Ever been hit in the face with a cream pie? Take it from me, it doesn't really hurt when it's merely squished into your face. But it can be painful if the pie is actually thrown, because a moving pie has kinetic energy. Any celestial body that spins, moves, or contains jiggling atoms — in other words, everything — seethes with kinetic energy. It's everywhere.

Anyway, as your car goes uphill, it actually gains energy — the potential energy of gravity, meaning that when you arrive at the top, you get a coupon for a free ride back down. The coupon never expires. That gravitational potential energy would patiently wait for a million years. But say you squander it immediately and coast downhill, gaining kinetic energy, while using up this gravitational potential energy. When you hit the brakes at the bottom, the car's kinetic energy gets transferred into heating the brakes. Heat is simply atoms in motion, which is more kinetic energy. Bottom line: Your brief, pointless ride displayed the changing forms of energy. None was ever spent. None was lost. There is only potential energy and kinetic energy, everywhere, assuming various disguises.

LIGHT ISN'T JUST *what* you see. It's what *makes* you see.

Now consider Betelgeuse. This star is on the brink of pulling off an unpleasant surprise for any alien attorneys who have offices on its planets. Someday, Betelgeuse's ancient core won't crank out enough energy to keep pushing its surface outward against its awesome gravity 5 million times greater than Earth's. That potential energy just lurks there like a ticking bomb. When the star collapses, so much potential energy will change into kinetic energy that atomic motion (heat) will suddenly build to unimaginable levels, releasing a brand-new warehouse of potential energy trapped within its atoms. This is a supernova. You don't want to be there.

Energy and force seem similar, but they're different: A force is a push or pull between two objects. Some forces, like the pie, work by physical contact. Others, oddly, act through empty space; no touching is needed.

There are only four fundamental forces: the strong force, weak force, electromagnetism, and gravity. The "strong force" glues protons together, which is a good thing if you value your body and its atoms. This force also keeps neutrons intact. Pry a neutron from its cozy atom-home, and it falls apart in 15 minutes. Leave it alone, and it lasts forever. It's like your car's toolbox.

The strong force works only at short distances about the diameter of a nucleus. That's why giant atoms like uranium are unstable. They're too big. Their outermost protons live where the force is weaker so that one occasionally falls off, changing the atom into a different element. They don't make elements like they used to.

The weak force works solely within atoms, too, and can induce radioactivity. We won't talk about it because nobody cares about the weak force.

Then there's electromagnetism. Its range is infinite. This wonderful force makes motors work and creates particles of light (photons). Photons carry this force from one place to another. When you observe anything through a telescope, what's really happening is that light is bringing the electromagnetic force from far-away empires and delivering it to your retina, where it causes biochemical reactions. In a word, vision. Light isn't just *what* you see. It's what *makes* you see.

The fourth force, gravity, is the most mysterious. Nobody really knows what it is. Like electromagnetism, its range is also infinite. It never falls off to zero. Gravity is what glues stars and galaxies together and also can rip them apart.

Force and energy. They're the heart and soul of astronomy.

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BY GLENN CHAPLE

Finding the right finder

You'd be surprised by the finder scopes available to today's amateur astronomers. The typical model is an **optical finder scope** — essentially, it's a miniature wide-field telescope. The numbers 6x30 signify its magnifying power (6x) and aperture (30mm) and are adequate size to use with a small refractor. For my 13-inch Dobsonian, I use a larger 8x50 finder.

These finders are the straight-through variety. Some companies offer **right-angle finder scopes** that afford a more comfortable eye position. A right-angle finder scope is a welcome option for anyone with neck or back problems.

Not all finders are optical. The simplest non-optical finder is a **peephole sight** — either a hollow metal or plastic sighting tube or a pair of square or circular plates with center holes through which you sight your target. These rudimentary finders work best with rich-field telescopes.

A step up from the peephole sight is the **unity finder**, which projects a small red LED dot in the finder field's center. Place the dot over your target, and the telescope is aimed. Some unity finders forego the red dot for either a circle or a series of concentric, illuminated "bull's-eye" circles.

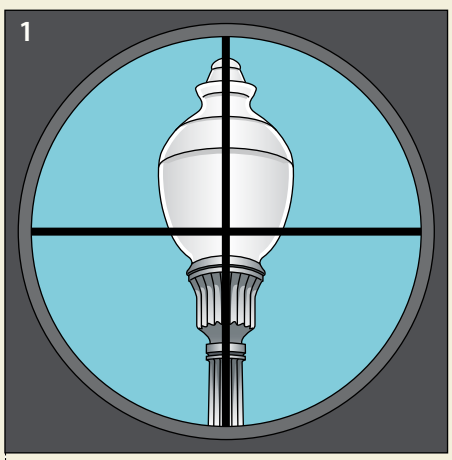
Unity finders do have drawbacks. They work well in star-rich regions, but falter where there are few naked-eye stars to guide the way. Also, unity finders are battery-powered. Forget to turn one off at the end of an observing session, and you'll have an unpleasant surprise next time you observe.

Amateur astronomers have yet another option for targeting sky objects: the **green-laser finder**. This finder projects a visible beam toward your target's location. Still, I wonder how you'd navigate in star-poor regions of the sky. Moreover, imagine a star party with hundreds of amateur astronomers plying the skies with green-laser finders. The locals might think an alien invasion is in progress!

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

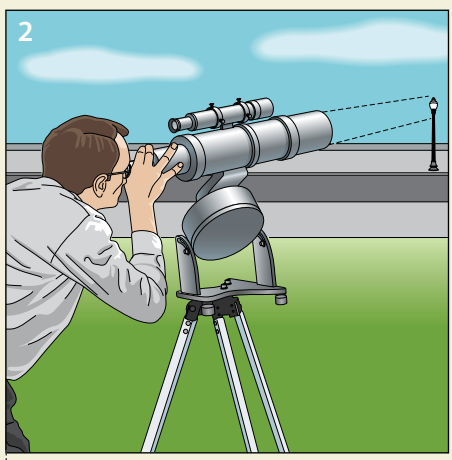
How to align your finder scope

If you are having trouble locating objects with your main telescope, the problem may lie with the finder scope. Make sure the finder's mounting bracket isn't loose. In a traditional two-ring, three-screw design, tightening the screws that attach the finder to the telescope will fix that. If you then peer through the main telescope's eyepiece and don't see your target object, your finder scope is out of alignment. Ideally, you should align a finder scope during the daylight to avoid fumbling around in the dark. Follow the steps below. — *G. C.*

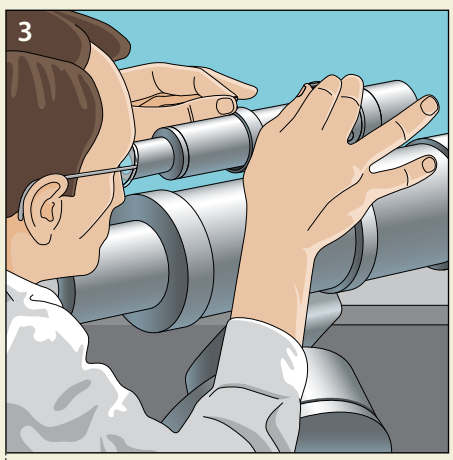


ASTRONOMY: THEO COBB

CENTER THE FINDER scope on a stationary target, such as a streetlight. Earth's rotation turns any sky object into a moving target. It's a lot easier to align a finder on something stationary.



WITH THE STREETLIGHT visible in the finder scope, maneuver the main scope until the streetlight appears in the middle of the eyepiece field. Once you center the object, lock the scope's mount in place.



WITHOUT MOVING the main telescope, use trial and error to adjust the set screws until the object is back in the crosshairs. Some finders sit in a single-ring bracket, but the alignment method is the same.

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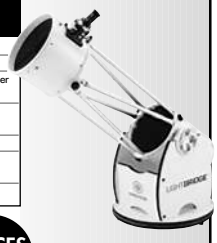

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BY PHIL HARRINGTON

Gone to the dogs

Face it, the night sky is for squares.

And triangles, circles, and all sorts of other geometric patterns. There's the Summer Triangle, the Winter Circle of Stars, and autumn's Great Square. In spring, we have a large diamond formed by the stars Arcturus, Spica, Denebola, and Cor Caroli.

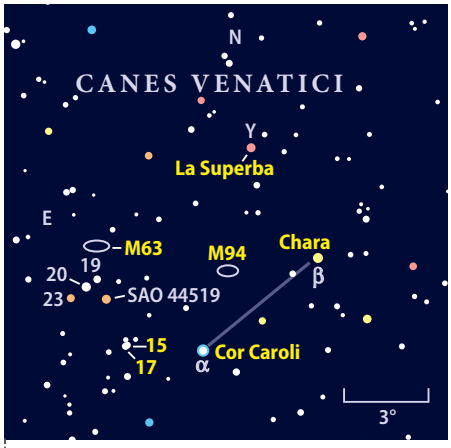
Others call this pattern the Great Diamond or the Spring Diamond.

I first bumped into the "Diamond of Virgo" while perusing the 1912 book *A Beginner's Star-Book* by Kelvin McKready. It's a fun little treatise that brought the sky down to Earth for an earlier generation.

While the diamond's other three facets are easy to spot, 3rd-magnitude **Cor Caroli** can be tough to pick out with today's light pollution. Look for it all alone under the crook of the Big Dipper's handle. Cor Caroli is one of spring's showpiece binary stars, although its two suns are difficult to distinguish through most binoculars. Even though they are separated by 19°, their widely disparate magnitudes of 3 and 6 make the stars tough to resolve at low powers. I've never had much luck splitting them through my 10x50 binoculars, but I can with the extra oomph from my 16x70s. Give it a try, and let me know how you make out at phil@philharrington.net.

Cor Caroli's constellation, Canes Venatici, contains two dogs owned by nearby Boötes the Herdsman. Only two stars are bright enough for naked-eye viewing: Cor Caroli and **Chara**, to its northwest. Personally, I can't see two dogs using just two stars. The best I can imagine is a hot dog!

What Canes Venatici lacks in naked-eye appeal, it makes up for by hosting some great hidden treasures. To see for yourself, start by finding Cor Caroli and Chara with your binoculars, and then look exactly halfway in between. Shift just to the northeast (upper left) of that center point, and take a careful look for a small, grayish smudge of light. See it? That's the spiral galaxy **M94**. At 8th magnitude, M94 is going to be tough to spot at first, but don't give up if you can't find it right away. Be patient. To help zero in, look for a small diamond of faint stars to the galaxy's north-northwest (upper right). I saw M94 recently through my 10x50 binoculars as a tiny, round disk highlighted by a faint, starlike center.



THE HUNTING DOGS won't lead you astray if you are on the prowl for bright, nearby galaxies during a night of binocular observing. *ASTRONOMY:* ROEN KELLY

Return to Cor Caroli, and let your attention drift about half a field east, to a pretty double star formed by the 6th-magnitude suns **15 and 17 Canum Venaticorum**. Striking as they are through binoculars, 15 and 17 form only a chance alliance from our earthly perspective. It turns out that 17, the easternmost of the two, lies just over 200 light-years away. You'd have to travel another 900 light-years to get to 15.

Move another binocular field to the northeast, and you should spot an obvious asterism of four stars that form a backward number 7. Although the stars — **19, 20, and 23 Canum Venaticorum**, and **SAO 44519** — are not physically related to one another, they create a unique pointer to help us find **M63**. Over 37 million light-years away, this challenging spiral galaxy floats just 1°, or the distance covered by two stacked Full Moons, north of the 7. Through my 10x50 binoculars, M63 looks like a tiny, cigar-shaped blur close to a very faint star. M63 is a little fainter than M94, so you'll need to support your binoculars very steadily to locate it.

Head back to the backward 7, and follow its aim toward the northwest for about one field. There, amongst all of the white stars, stands a deep-red ruby known as **La Superba**, a name bestowed by the 19th-century Italian astronomer Father Angelo Secchi (1818–1878). Cataloged more formally as Y Canum Venaticorum, this beautiful variable star flickers between magnitudes 5 and 6.5 over a period of about 160 days. When we look its way, we are seeing a rare example of a red-giant star that is overly rich in carbon. Nearing the end of its life, La Superba is releasing carbon into space. These carbon molecules absorb the blue end of the spectrum to give the star its vivid color.

Much more exists in Canes Venatici, including a fun group of stars that was misidentified as a rogue open cluster. Come over to Astronomy.com this month to continue your exploration.

Next month, we pay a binocular visit to our nearest neighbor. Until then, remember, when it comes to touring the universe, two eyes are always better than one.

ONLINE EXTRA Find more binocular objects worth hunting down in Canes Venatici at www.astronomy.com/toc.

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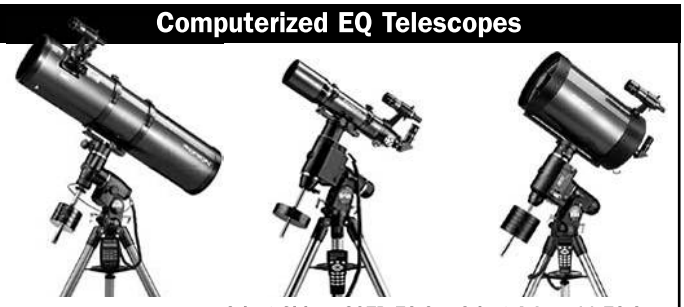

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BY STEPHEN JAMES O'MEARA

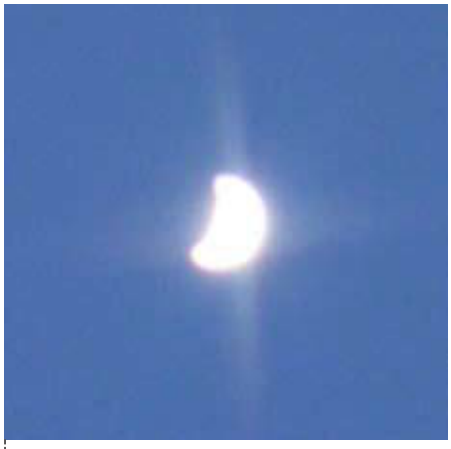
Venus and the South

Last month, I wrote about how Walt Whitman's poem, *When Lilacs Last in the Dooryard Bloom'd*, compared President Abraham Lincoln and his last days to Venus. But did you know Lincoln spotted Venus in broad daylight — without optical aid — shortly before his death?

The sighting occurred March 4, 1865, the day of Lincoln's second inauguration. After concluding his speech at the Capitol building, the president entered his two-horse carrier and joined a choreographed procession up Pennsylvania Avenue to the White House. Sergeant Smith Stimmel, one of Lincoln's bodyguards that day, continues the tale in his 1928 book, *Personal Reminiscences of Abraham Lincoln*:

"Shortly after we turned onto Pennsylvania Avenue, west of the Capitol, I noticed the crowd along the street looking intently, and some were pointing to something in the heavens toward the south. I glanced up in that direction, and there in plain view, shining out in all her starlike beauty, was the planet Venus. It was a little after midday at the time I saw it, possibly near one o'clock; the sun seemed to be a little west of the median, the star a little east. It was a strange sight. I never saw a star at that time in the day before or since. The superstitious had had many strange notions about it, but of course it was simply owing to the peculiarly clear condition of the atmosphere and the favorable position of the planet at that time. The President and those who were with him in the carriage noticed the star at the same time."

Carl Sandburg, in his 1939 classic *Abraham Lincoln: The War Years* (Volume IV), notes that Lieutenant Ashmun and his cavalry escort also viewed Venus that day. Ashmun said it was "the first and only time that most of us ever saw that star at that hour of the day." The apparition — an omen to some, according to Sandburg — also was mentioned in the accounts of the day at the close of the high ceremonial as "a bright star visible in the heavens."



VENUS' BRIGHTNESS in May will allow daytime observers to view the planet. Try spying Venus through your telescope to identify its phase. PETER AND SARAH OPPENHEIM

This sighting is similar to one made at another high ceremonial in 1796 — one in honor of Napoleon Bonaparte after he defeated the Austrian army at Lodi in Italy. Henry White Warren tells the classic tale in his 1879 book, *Recreations in Astronomy with Directions for Practical Experiments and Telescopic Work*:

"Upon repairing to Luxembourg when the Directory was about to give him a fete, [Bonaparte] was much surprised at seeing the multitude paying more attention to the heavens above the palace than to him or his brilliant staff. Upon inquiry, he learned that these curious persons were observing with astonishment a star which they supposed to be that of the conqueror of Italy. Napoleon himself was not indifferent when his piercing eye caught the clear lustre of Venus smiling upon him at mid-day."

If by chance

Seeing Venus in the day with the unaided eye can be an awesome experience. At its brightest, our sister planet shines at magnitude –4.5, making it the most brilliant object in the sky, apart from the Sun and Moon. It is most prominent to the naked eye when seen high in the sky at or near greatest elongation (about 47° from the Sun). Venus met these conditions in both historical sightings mentioned previously.

Still, seeing the planet in the daytime can be a difficult observation that requires a crystal-clear sky and precise knowledge of where to look. To see Venus, that tiny "star" must fall directly on the eye's "yellow spot," or macula, the central region of the retina. This is where the eye's day-sensitive cone cells reside. Even then, there's no guarantee of success unless the observer is patient and knows how to focus his or her eyes at infinity.

Paradoxically, as the festive crowds at the Lincoln and Bonaparte ceremonials attested, Venus can be detected in the daytime with no prior knowledge of the object's whereabouts and minimal effort. It can be seen, in other words, simply by chance. All you need is the planet to be near a distant terrestrial object that's the center of your attention. If that object is about 600 feet (180 meters) away, your eyes will focus at infinity, allowing the eye's cone cells to register in sharp detail anything on or near that object out to about 2°.

During Lincoln's inaugural procession March 4, 1865, Venus would have been just above the treetops that line the south side of Pennsylvania Avenue. Clearly, someone must have turned his or her attention to the treetops and spied the daytime "star"

while waiting for President Lincoln to pass. In the case of Bonaparte's party in 1796, someone clearly noticed Venus near some structure on the Luxembourg Palace while waiting for the Little Corporal to arrive.

A passing cloud also can draw an unconscious eye to the planet and help sharpen your focus. In fact, on January 12, 2007, some wispy cirrus clouds assisted me in my search for C/2006 P1 (McNaught) in broad daylight from the nearly 14,000-foot-high (4,250m) summit of Hawaii's Mauna Kea. Actually, the comet, which was then shining roughly at magnitude –5, was quite easy to see with the unaided eye only about 10° from the Sun, whose disk I blocked with a Jeep's roof. But its presence near the cloud made focusing superfluous — the comet stood out immediately from the background sky.

I then used irregularities in the moving cloud as guideposts when I helped my friend Amos Meyers — who is severely astigmatic — to see Comet McNaught. He found the comet difficult to spot without visible landmarks, but once he got the comet centered in his eye's fovea, he saw it clearly. The next day, from my home in Volcano, Hawaii, I once again used a passing cloud to help my wife, Donna, partake in this exciting moment in astronomical history.

Although this daytime comet is now but a memory, there will be others. Meanwhile, this month you can start practicing your daytime observing skills on finding Venus, which will shine brilliantly at magnitude –4.2 during mid-May. Our sister planet will be about as bright and far away from the Sun as it was during the ceremonials for Abraham Lincoln and Napoleon Bonaparte years ago. Then, on May 19, when Venus is highest in the daytime sky, a waxing crescent Moon will slide within 3° of the planet, serving as a perfect guiding light.

E-mail me at someara@interpac.net to let me know how you did with daytime observations of Venus this month. Also, tell me about any daytime sightings you made of Comet McNaught in January. Be sure to include any tricks you used to pull it out from the background sky.

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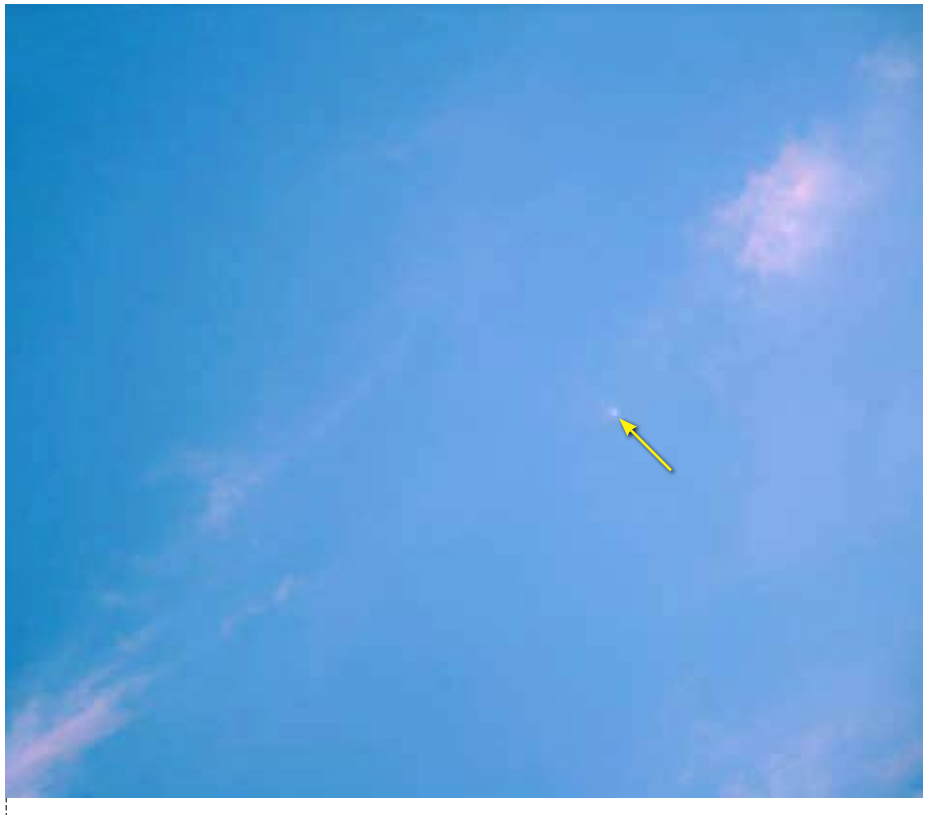
AN INFANTRY UNIT marched down Pennsylvania Avenue in Washington in May 1865, during the grand review of the army, captured by Mathew Brady. Two months earlier, careful observers had spied Venus just above the trees to the right of this view.



STEPHEN JAMES O'MEARA

COMET MCNAUGHT (arrow) proved a challenge in January for daytime observers. To separate the comet from the sky, O'Meara used a passing cloud, such as in the upper-right corner.

MRO data By February, just 3 months into its planned 2-year mission, the Mars Reconnaissance Orbiter already had returned to Earth more data than any previous Mars mission.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

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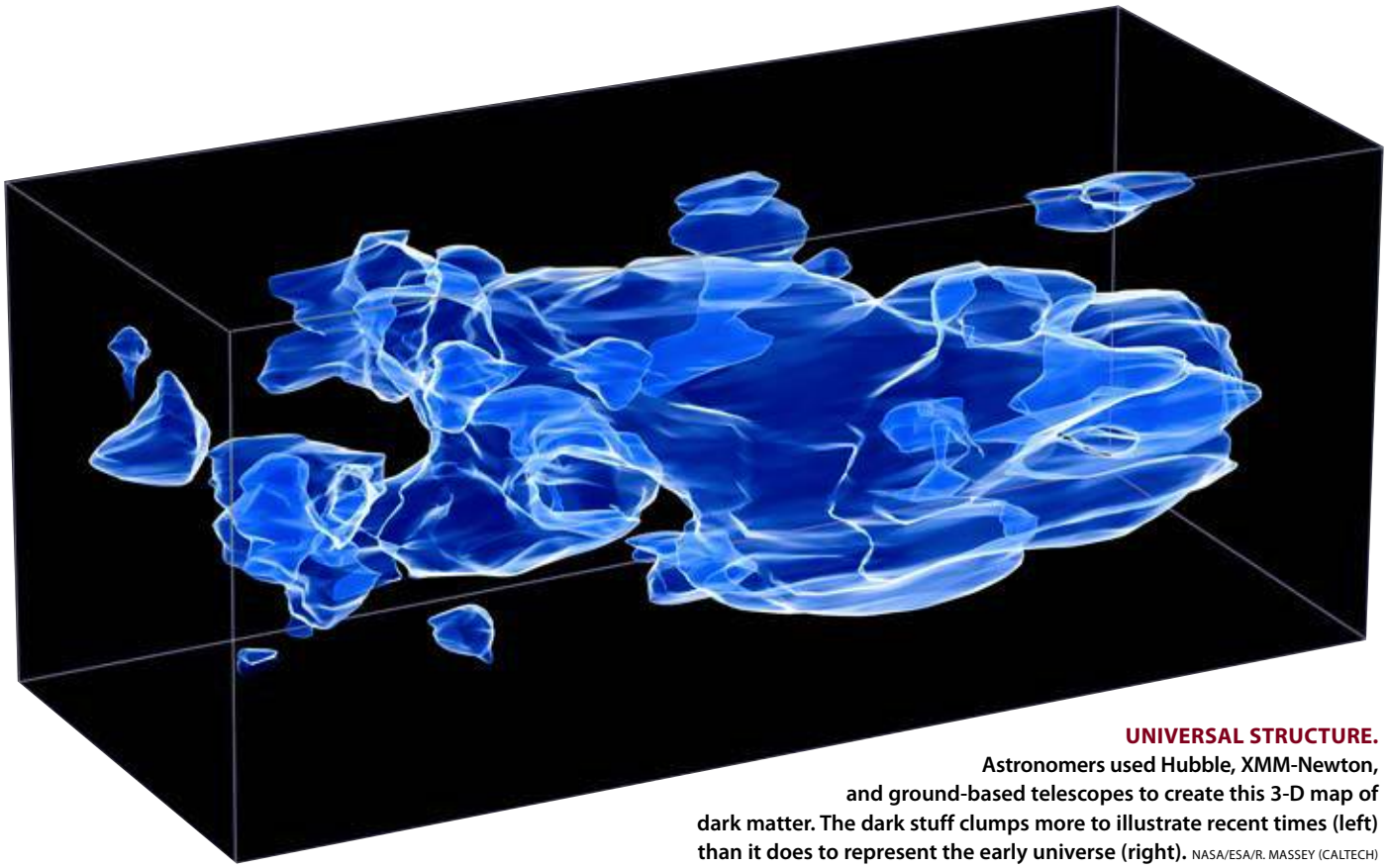

UNIVERSAL STRUCTURE. Astronomers used Hubble, XMM-Newton, and ground-based telescopes to create this 3-D map of dark matter. The dark stuff clumps more to illustrate recent times (left) than it does to represent the early universe (right). NASA/ESA/R. MASSEY (CALTECH)

22 Did the Viking landers kill?

24 The Eagle has a blast

26 A red-rocket milestone

27 The Milky Way's family grows

Astronomers discover cosmic framework

An international team of astronomers has created a three-dimensional map of dark matter. "For the first time, we've been able to map out this invisible and mysterious dark matter," says Caltech's Richard Massey. Dark matter — a substance detected only through its gravitational effect on normal matter — accounts for most of the universe's mass.

The milestone project, dubbed the Cosmic Evolution Survey (COSMOS), is led by Caltech astronomer Nick Scoville. The study required nearly 1,000 hours of Hubble time; 400 hours of observations with the European Space Agency's XMM-Newton X-ray satellite; and galaxy color data from several ground-based telescopes.

But the Hubble images were the key factor, allowing team members to glimpse weak gravitational lensing — distortions in the shapes of background galaxies — caused by intervening dark matter.

The COSMOS map shows the largest visible structures are filaments 60 million light-years long that contain 2 trillion times our Sun's mass. "Dark matter collapsed first," says Massey. "Without it, the universe as we know it today wouldn't exist." The map shows visible galaxies then formed within the dark-matter framework.

The team presented its findings January 7 at the American Astronomical Society meeting in Seattle. **— FRANCIS REDDY**

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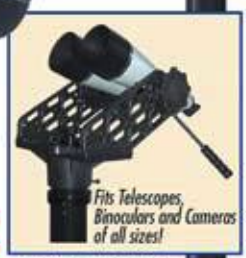

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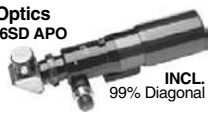

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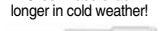

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Blind eye The National Research Council says that if nothing changes, the number of active U.S. Earth-observing satellite programs could fall from 29 currently to five by 2020.

QUICK TAKES

HUBBLE TROUBLE
Hubble's Advanced Camera for Surveys went into "safe mode" January 27, when its electronics failed. Science operations resumed soon after with other instruments.

SAVE THE DATE
NASA has scheduled the space shuttle Atlantis for a September 11, 2008, launch to begin the next Hubble servicing mission.

TRIPLE QUASAR
Astronomers have discovered the first triple quasar, a beacon shining 10.5 billion light-years from Earth.

RHEA REVEALED
A Cassini spacecraft flyby of Saturn's moon Rhea shows it to be a homogeneous mix of ¼ rock and ¾ water ice.

GREAT BALL OF FIRE
On January 4, a Russian booster rocket streaked across Colorado and Wyoming skies as it reentered Earth's atmosphere.

COROT ON THE GO
On December 27, the French-led COROT mission lifted off from Baikonur in Kazakhstan on a mission to probe stellar interiors and find transiting exoplanets.

MOVIN' ON UP
S. Alan Stern, a member of *Astronomy*'s Editorial Advisory Board, has been named NASA's associate administrator for the Space Science Directorate.

NASA MOON-IMPACTOR
NASA has approved key elements of "LCROSS," a mission to look for water by striking near the Moon's south pole in January 2009.

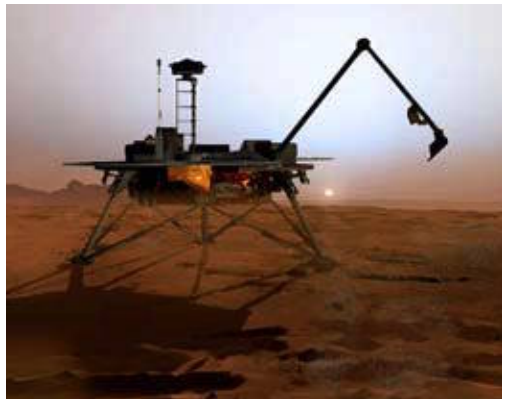
HIGH-FLYING ADS
For $5,000, California's JP Aerospace says it will shoot video of company logos at the edge of space. The billboards will reach 100,000 feet (30,500 meters) aloft high-altitude balloons.

Did the Viking landers kill?

Thirty years ago, the twin Viking landers touched down on Mars and began to scoop and sniff the martian soil for signs of life. But because of the way the landers' onboard laboratories conducted the search for living organisms, they may have inadvertently baked and drowned any life they found.

At least that's what Dirk Schulze-Makuch of Washington State University in Pullman and Joop Houtkooper of Justus Liebig University in Giessen, Germany, argued January 7 at a meeting of the American Astronomical Society in Seattle. The scientists propose the findings of the 1976 Viking experiments can be explained if the biochemical basis for life is based on a mixture of water and hydrogen peroxide, which remains fluid down to –68° F (–56° C), and not the salty water that fills most earthly cells.

Schulze-Makuch and Houtkooper contend the Viking landers failed to detect life because they were searching for the wrong kind of life. Moreover, at least two of the Viking experiments would have killed off any hydrogen-peroxide-based organisms in the soil.



CORBY WASTE (NASA/JPL)

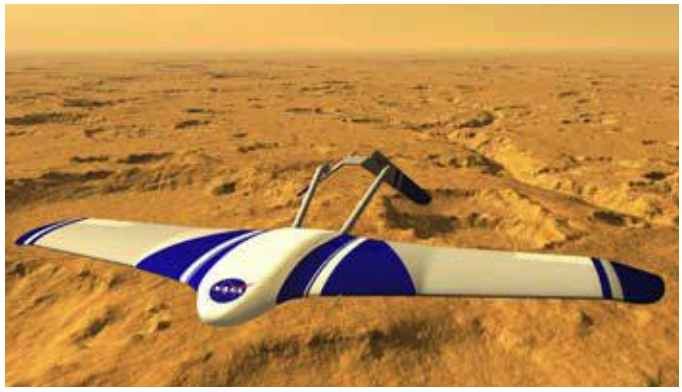
PHOENIX LANDER. NASA's next mission to Mars will explore the Red Planet's far north and may detect organic compounds produced by life.

The next opportunity to gather hard evidence for the hydrogen-peroxide hypothesis will begin in May 2008. That's when the Phoenix lander, scheduled to launch this August, is slated to touch down in Mars' arctic region. The lander's gear includes an onboard chemical laboratory that should be able to detect organic compounds produced by martian microorganisms, either living or long-dead. **— DANIEL PENDICK**

NASA names Scout mission finalists

The Phoenix mission to Mars, set to launch in August, is the first of NASA's planned series of relatively small, low-cost Scout missions. But the final two contestants to be the next Scout — slated for departure as early as 2011 — have just received $2 million each for feasibility studies. They are the lone survivors of an original field of 26 proposed missions.

Dubbed The Great Escape (TGE) and the Mars Atmosphere and Volatile Evolution (MAVEN) missions, respectively, they both focus on the martian upper atmosphere. Their chief goal is to understand how the atmosphere has changed over time.



NASA/LRC

GROUNDED. The proposed ARES Mars plane failed to make the final cut to be the next Scout mission.

Although now cold and dry, Mars' atmosphere may have once been dense, warm, and moist enough for liquid water to flow on the planet's surface. Over the next 9 months, NASA will provide money for feasibility studies of both missions. Then, one will be chosen to receive full funding of $475 million to go to Mars.

Edged out of the competition was the Aerial Regional-scale Environmental Survey (ARES) mission, which would have sent a rocket-powered airplane soaring over the martian surface to measure the planet's magnetic field, search for subsurface water, and detect gases of possible biological origin. **— D. P.**

Understand the Fascinating Science of Climate Change

Review the most up-to-date scientific facts in 12 compelling lectures

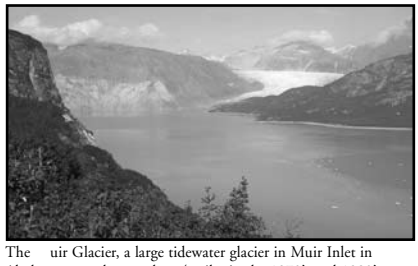
Recently the Intergovernmental Panel on Climate Change concluded that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level." Representing a consensus of hundreds of scientists, the report went on to note that human activity is "very likely" the cause.

This course of 12 half-hour lectures reviews the most up-to-date research on climate change, explaining the concepts, tools, data, and analysis that have led an overwhelming number of climate scientists to conclude that Earth is warming and that we humans are in great part responsible.

Whatever your views on climate change, it's important to understand how the current scientific consensus on global warming evolved out of basic physical principles and a broad range of observations. **Earth's Changing Climate** addresses only scientific issues and makes no policy recommendations. Instead, this course is designed to serve as your personal scientific briefing to equip you to engage knowledgeably in one of the most important environmental issues of our time. In Lectures 1–6 you will focus on the scientific basis of climate; then in Lectures 7–12 you will come to understand the human role in climate change and explore projections of future climate.

The Evidence Mounts

Like many scientific problems, the gradual assembly of a detailed picture of past, present, and future climates has involved creative detective work. For example, scientists traditionally test their theories by changing different variables, but this has not been possible with theories about climate change on Earth for two reasons: It's unwise to transform the planet just to see what will happen, and there are not multiple Earths to serve as test subjects. However, you'll see that researchers have been able to identify cases where nature has done the experiments.



The uir Glacier, a large tidewater glacier in Muir Inlet in Alaska, retreated more than 4 miles in the 1970's and 1980's alone.

As the evidence mounts, scientists will continue to refine their picture of what the climate is doing and where it is heading and society will continue to grapple with this problem. You can begin to address it yourself—intelligently and prudently—by investing six stimulating and rewarding hours with this course.

About Your Professor

Dr. Richard Wolfson is the Benjamin F. Wissler Professor of Physics at Middlebury College, where he also teaches Climate Change in Middlebury's Environmental Studies Program. He completed his undergraduate work at MIT and Swarthmore College, graduating from Swarthmore with a double major in Physics and Philosophy. He holds a master's in Environmental Studies from the University of Michigan and a Ph.D. in Physics from Dartmouth.

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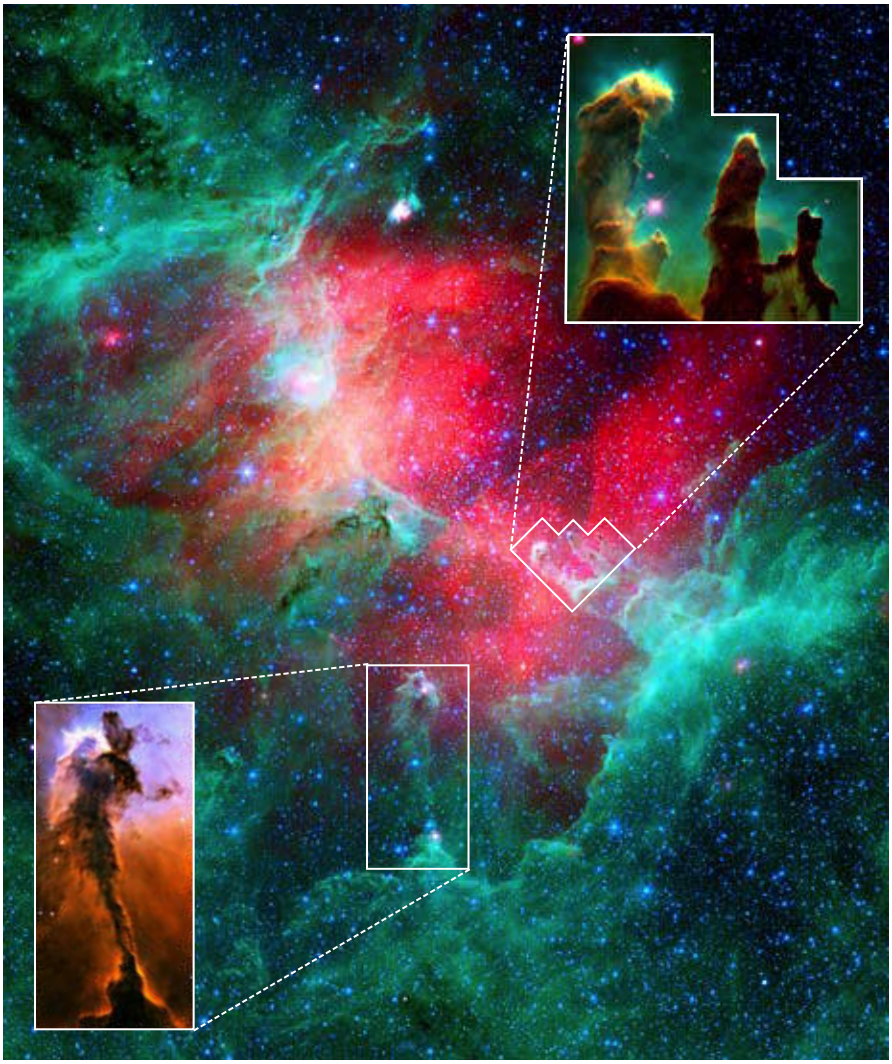
Brit invasion

British space companies propose two lunar missions by 2010. "MoonLITE" would fire instrumented darts into the Moon's surface; "MoonRaker" would land.



NASA/JPL-CALTECH/N. FLAGEY (IAS/SSC) AND A. NORIEGA-CRESPO (SSC/CALTECH)

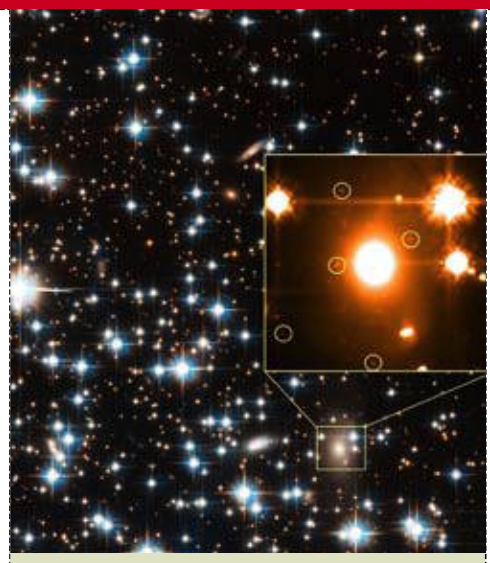
HOT DUST. **The Spitzer Space Telescope's infrared eyes peer into the Eagle Nebula and find hot dust (shown in red) linked to a supernova explosion. The famous pillars seen by Hubble (insets) may not survive the blast, although we won't see the effects for centuries.**

The Eagle has a blast

A new image from NASA's heat-sensing Spitzer Space Telescope reveals a cloud of hot dust at the heart of the Eagle Nebula (M16). The dust is so hot, astronomers say, only a stellar explosion could have been responsible.

The explosion's shock wave already may have destroyed features made famous in a 1995 Hubble Space Telescope image of the nebula. The 20 or so massive stars at M16's center produce high-energy radiation and strong outflows that carve out a hollow in the nebula's dense gas and dust. Hubble imaged three dusty columns — dubbed the "pillars of creation" — sculpted by these effects.

"I remember seeing a photograph of these pillars more than a decade ago and being inspired to become an astronomer," says Nicolas Flagey of the Institut d'Astrophysique Spatiale in Orsay, France. "Now, we have discovered something new about this region we thought we understood so well." Flagey presented his findings at January's American Astronomical Society meeting in Seattle. **— F. R.**



DISTANT GLOBULARS. **A billion light-years beyond the bright stars of globular cluster NGC 6397, Hubble imaged an elliptical galaxy (inset) with numerous globular clusters (circles) of its own.**

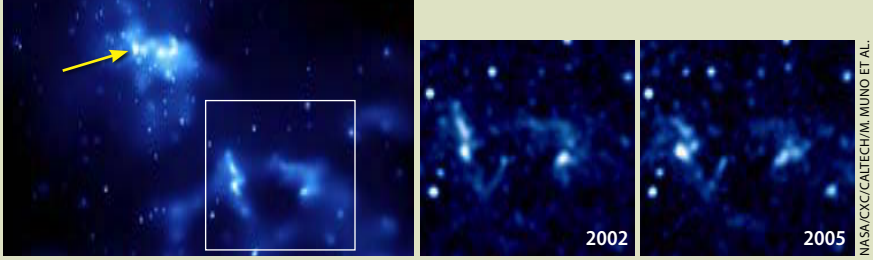
NASA/ESA/H. RICHER (UBC)/J. KALIRAI (UCSC)

Most distant star clusters found

Call it a stellar case of serendipity: While observing the Milky Way globular cluster NGC 6397 with the Hubble Space Telescope, astronomers at the University of British Columbia (UBC) in Vancouver discovered the most distant globular star clusters yet seen. Further work with the 8-meter Gemini South Telescope in Chile revealed the clusters are more than 1 billion light-years away.

"They are by a long shot the farthest system we've ever seen," says UBC's Harvey Richer, who shares the discovery with his former doctoral student Jason Kalirai. Indeed, the clusters lie 10 times farther than any previously observed. Kalirai presented the finding at January's American Astronomical Society meeting in Seattle.

The Hubble image shows about 200 globular clusters surrounding a giant elliptical galaxy. Richer says the cluster system — seen now as it existed more than a billion years ago — offers an opportunity to test and refine theories of how globular clusters evolve. **— D. P.**



NASA/CXC/CALTECH/M. MUNO ET AL.

X-RAY ECHO. **Fifty years ago, the black hole in the Milky Way's core (Sgr A*) had a meal. The X rays emitted recently reflected off two distant gas clouds (insets).**

Milky Way's black hole has lunch

Five decades ago, the 3-million-solar-mass black hole at our galaxy's center swallowed a mass equivalent to Mercury. The resulting outburst was about 1,000 times brighter and lasted well over 1,000 times longer than any recent outburst observed by the Chandra X-ray Observatory.

During the outburst, which may have lasted as long as 2 years, the area near the black hole would have blazed 100,000 times brighter than it does now. X rays from the outburst continued moving through space. When this pulse reached nearby gas clouds, it illuminated them, creating the radiation Chandra observed.

"Our data show it has been 50 years or so since the black hole had its last decent meal," says Michael Muno of Caltech in Pasadena. "This is nothing like the feasting that black holes in other galaxies sometimes enjoy, but it gives [us] unique knowledge about the feeding habits of our closest supermassive black hole."

Muno presented the results January 10 at the American Astronomical Society meeting in Seattle. — **F. R.**

May 1982

25 years ago in *Astronomy*

In "The Planets or Bust," writer Van Kane examined NASA's steadily shrinking budgets, and how they were forcing the space agency to scale back to just a few planetary missions. In order to help revive the planetary program, NASA was championing the 1980s and 1990s as an era of low-cost missions that were small in scale and tightly focused — what would later become the agency's "faster, better, cheaper" vision.

Rather than collecting atmospheric, geologic, and magnetospheric data all in one mission, limited funds meant missions concentrated on a single facet. The idea eventually worked, and the Discovery program of planetary missions became an unqualified success.

May 1997

10 years ago in *Astronomy*

The cover of our May 1997 issue featured an image of the Lagoon Nebula (M8) taken by the Hubble Space Telescope. Hubble's look inside this giant stellar nursery, located 5,000 light-years from Earth, gave astronomers their closest look to date.

The images revealed complex structures in the nebula. Associate Editor Robert Naeye's "At the Heart of the Lagoon" described these structures and explained how radiation and stellar winds sculpted them.

Later Hubble images confirmed this process occurs in many star-forming regions. — **KATIE NEUBAUER**

BRIEFCASE

China wipes out satellite

China destroyed one of its own Earth-orbiting weather satellites with a ground-based ballistic missile January 11. The test followed three unsuccessful attempts. Satellites in low Earth orbits are vulnerable to such missiles, and debris from the destroyed satellite raises the already high level of junk in orbit that threatens other spacecraft. The test prompted immediate protests from the United States, Canada, and Australia. **— LAURA LAYTON**

India's big success

On January 10, India's space agency launched a capsule into Earth orbit from a launch pad near Chennai. On January 22, the capsule returned to Earth, splashing down in the Bay of Bengal. This marks India's first major success in deploying reusable spacecraft and the first step toward putting an astronaut in space, which the country hopes to do by 2014. **— L. L.**

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WORKING OUT. **Astronaut Kenneth Bowersox uses a special body harness aboard the International Space Station to hold himself onto a treadmill, simulating the force of gravity.**

Boning up for Mars

The current exercise regimen aboard the International Space Station (ISS) would not maintain adequate bone strength for astronauts to safely journey in zero-G to distant destinations like Mars. According to recent medical research compiled by Thomas F. Lang of the University of California, San Francisco, ISS crew members lose as much bone density per month as most earthbound women lose per year after menopause. After a flight to Mars, astronauts could become vulnerable to crippling bone fractures.

But all hope for long-distance space exploration is not lost, says acting ISS program scientist Julie Robinson, who presented Lang's data January 8 at the American Institute of Aeronautics and Astronautics meeting in Reno, Nevada.

Robinson says the harnesses used to fasten ISS crew members to treadmills, thus simulating the pull of gravity, will be redesigned to apply higher exercise stress to the body without causing discomfort. NASA will also evaluate the benefit of bone-building medications called bisphosphenates to counter the loss of bone density due to weightlessness. "This is a solvable problem," Robinson says. **— D. P.**

A red-rocket milestone

A half century ago, on May 15, 1957, a rocket appeared that would revolutionize transportation, science, and human thought. This "magic carpet" was the R-7 missile developed by a Russian team led by Sergey Korolyov (1907–1966). While other models of launch vehicles have arisen, flourished, and vanished, descendants of the R-7's original design still fly into space. More than 1,800 have been launched so far, and many more will follow.

The R-7, or "semyorka" in Russian slang ("sem" is Russian for "seven"), had a controversial birth. Moscow funded it to prepare for the possibility of a nuclear war. But Korolyov, a life-long spaceflight nut, had other intentions. He built features into the rocket that would prove invaluable for space missions — but which made it such a clumsy weapon only small numbers were deployed. It was soon replaced as a weapon-delivery system by new generations of missiles from other factories.

The R-7 looked different from other rockets built before 1957. Neither long and sleek and finned, nor stacked stage upon stage in a tapering tower, it looked like nothing so much as a bundle of asparagus stalks. A long, central core was flanked by four independent boosters, each identical at the business end to the central core, but tapering to a point where they joined the core near its top.

This design allowed the missile to have maximum thrust when it needed it most — when it was lowest and heaviest — and then cast off the excess weight of emptied fuel tanks and rocket engines when it got higher, lighter, and faster. The United States independently developed the idea of "strap-ons" a few years later, for the Titan-3 booster. They later became a key design feature of the Delta and Atlas rockets, and even the space shuttle.

NASA/MSFC

BOTTOMS UP. **The business end of the R-7 has five rockets, each with one engine having four thrust chambers.**

But Korolyov's R-7 didn't just go in for multiple parallel staging — even its rocket engine was "multiple." When the engine designers found they couldn't build a large thrust chamber with the desired power, Korolyov had them build an engine with one set of pumps but four separate nozzles — another innovation that has stood the test of time.

The design proved so robust, it has been upgraded and refined for half a century. Russia introduced the latest version — the "Soyuz-2-1B" booster — last year. Considering where it came from, a weapons test that exploded less than a minute into its maiden flight half a century ago, the rocket must be considered the finest example in human history of converting swords into plowshares — and into magic carpets. **— JAMES OBERG**

Rovers get improved brains

The twin Mars rovers Spirit and Opportunity have delighted their proud parents at NASA's Jet Propulsion Laboratory (JPL) all through their wonderful ones, terrific twos, and thrilling threes. In January, both rovers began what should be their fantastic fourth years, thanks to software updates that will make the robots smarter.

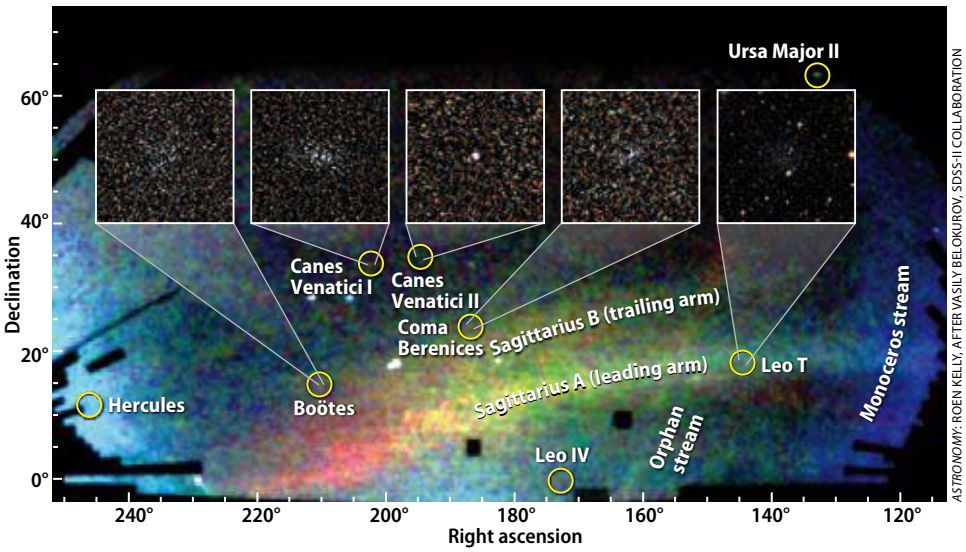
One update enables the rovers to recognize dust devils and clouds in the atmosphere. Now, only images containing those features will be returned to Earth.

Another update confers a skill called "visual target tracking." With this, a rover can constantly identify and navigate toward a target of interest — say, a boulder.

Finally, the rovers will be better able to avoid potential hazards. Before the software improvements, hazard management was more akin to trial and error. — D. P.

Pluto plan

Streator, Illinois — birthplace of Pluto discoverer Clyde Tombaugh — will host an expo May 18–19 in hopes of upgrading the dwarf planet's reputation.



ASTRONOMY: ROEN KELLY; AFTER VASILY BELOKUROV, SDSS-II COLLABORATION

NEW NEIGHBORS. Astronomers have found eight previously undetected dwarf galaxies near our galaxy. Seven appear to be satellites, while the eighth, Leo T, may be just passing by.

The Milky Way's family grows

While mapping streams of stars in the Milky Way's halo, astronomers found seven faint galaxies orbiting our own. An eighth object may belong to a new class of "free-floating" galaxies unbound to the Milky Way.

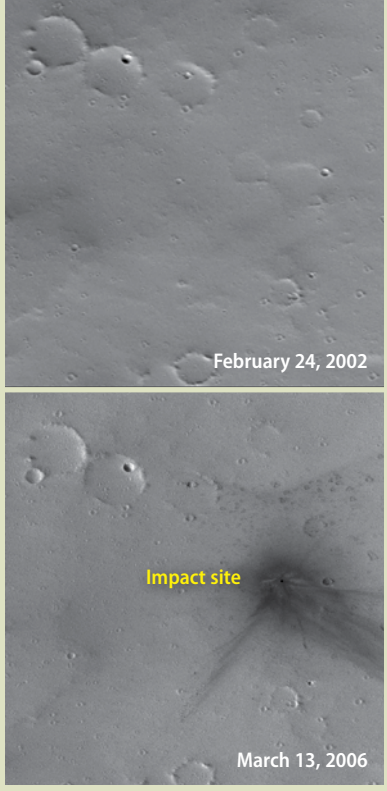
The seven orbiting dwarfs lie between 100,000 and 700,000 light-years away and contain a few million stars at most. Several appear to be near disruption, probably due to the Milky Way's gravity. Cambridge University's Daniel Zucker presented the team's findings in January at the American Astronomical Society's meeting in Seattle.

The team found the new galaxies by processing imaging data from the Sloan Digital Sky Survey. The astronomers eliminated red, nearby stars. Then, sophisticated computer algorithms churned through the data to find groupings of related stars. Two of the new dwarfs lie in the constellation Canes Venatici, one in Boötes, one in Leo, one in Coma Berenices, one in Ursa Major, and one in Hercules.

The eighth object is the most intriguing. Named Leo T, the galaxy is about 1.4 million light-years away, on the fringes of the Milky Way's gravitational influence.

Leo T's stellar glow amounts to only 50,000 Suns, but some of its stars formed within the last billion years. By contrast, all the other new dwarfs contain exclusively old stars. Further, radio data indicate Leo T holds lots of neutral hydrogen gas — the fuel for making new stars. "This is basically the smallest, faintest star-forming galaxy known," Zucker notes. — **F. R.**

ROVERS AT 4. Spirit spent this past winter in Gusev Crater. By spring, the rover will explore Mars with updated software. NASA/JPL/CORNELL



NASA/JPL/MSSS

MARTIAN CRATERS. In 2006, the MGS spacecraft imaged a crater that didn't exist 4 years earlier. The new crater has a diameter of 65 feet (19.8 meters).

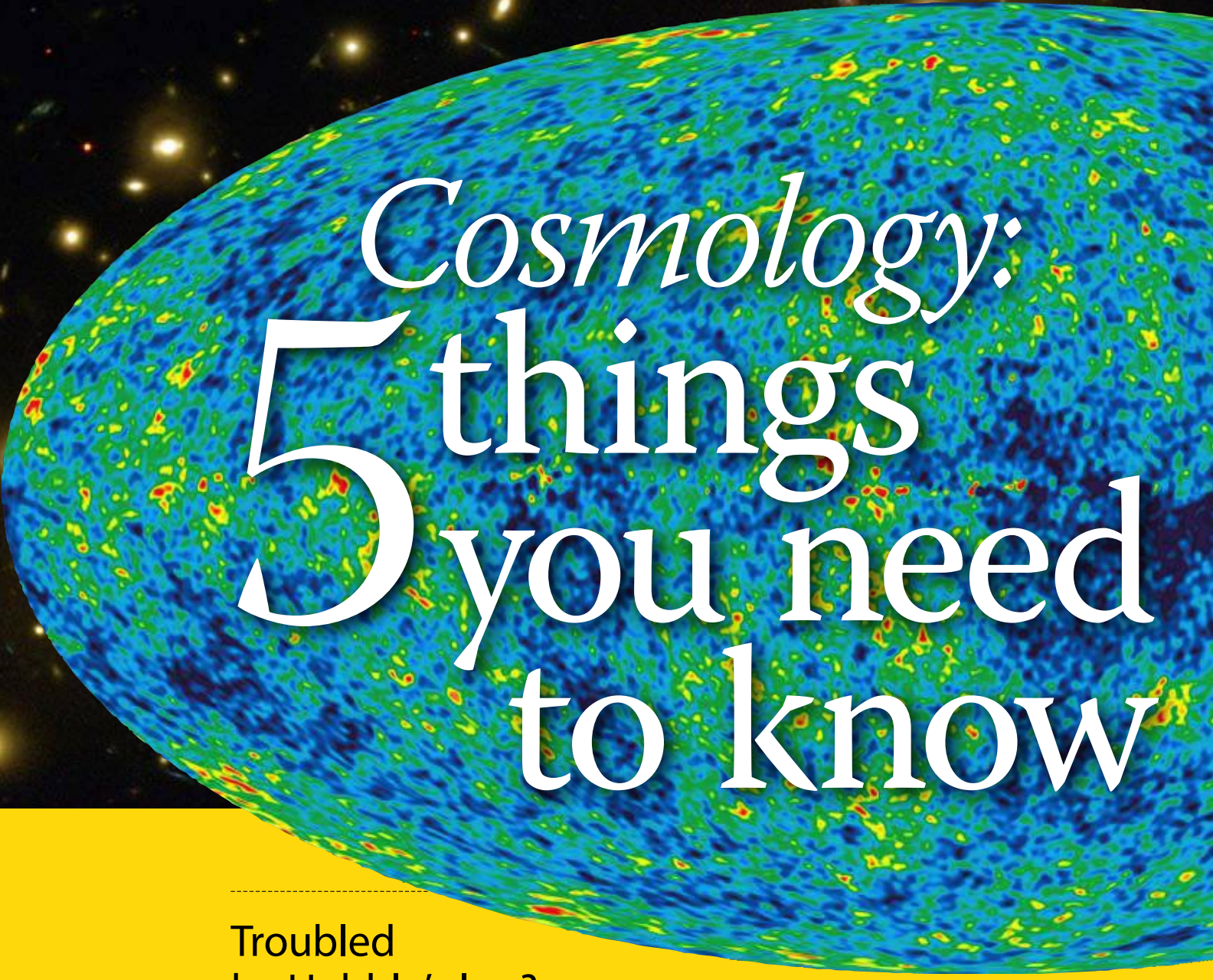
Mars gets blasted from above

Images taken by the now-defunct Mars Global Surveyor (MGS) spacecraft show fresh impact craters appear about as often as expected. If you lived on the Red Planet, chances are a meteoroid would crash close enough that you'd hear an impact every 10 to 20 years.

About a year ago, Michael Malin of Malin Space Sciences Systems and the MGS imaging team started comparing early photos with more recent ones, looking for fresh impacts. They found 20 impact sites with craters ranging from about 7 feet (2 meters) to 490 feet (150m) in diameter. Seven of the 20 impact events formed multiple craters.

Most of the new impact craters appear dark, suggesting the impacts removed light-colored dust. A few have light-toned ejecta, however, which implies those impacts excavated lighter subsurface material.

The cratering rate on Mars appears consistent with that of our Moon. This means areas devoid of craters must be relatively young, and some process must be removing craters. The imaging team reported its findings in the December 8 issue of *Science*. — **RICHARD TALCOTT**

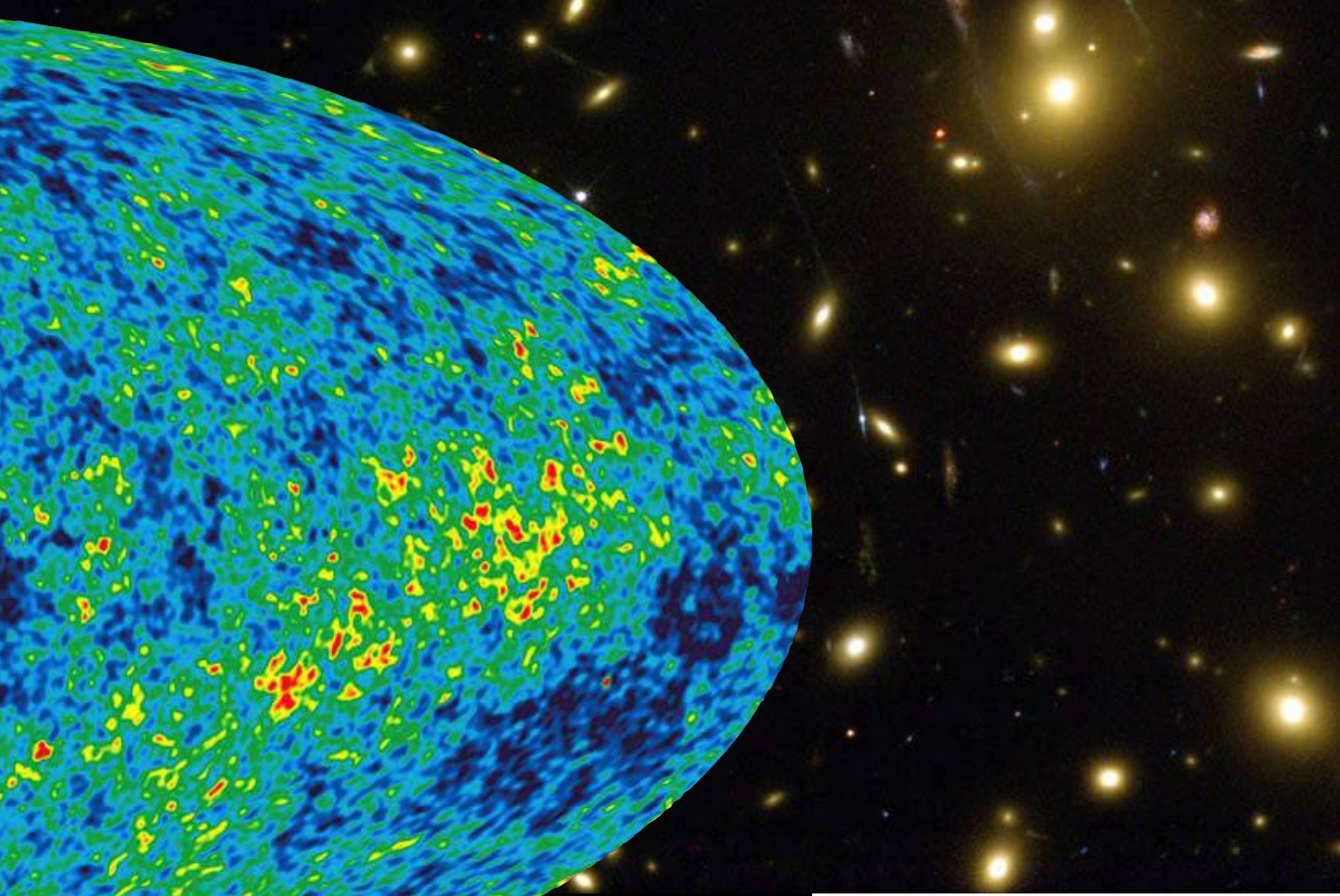


Cosmology: 5 things you need to know

Troubled by Hubble's law? Perplexed by the Big Bang? Tune up your cosmic knowledge with answers to cosmology's big questions. /// BY LIZ KRUESI

Cosmology's goal — to understand the origin and evolution of the universe — is nothing if not ambitious. Less than a century ago, astronomers discovered most galaxies are moving away from us and revealed the astounding fact that our universe is expanding. A few decades later, they realized a faint hiss of radio waves all over the sky arose from photons emitted shortly after the universe came into being. Last year, a spacecraft called WMAP, which is dedicated to exploring this cosmic microwave background, turned up compelling evidence that the universe underwent an earlier phase of hyper-expansion called inflation.

Some call today cosmology's golden age. Yet, for all its ongoing progress, some of cosmology's most fundamental ideas remain hard to grasp. *Astronomy* takes on the top five sources of cosmic confusion — the biggest stumbling blocks in understanding cosmologists' current portrait of the universe.



THE BIG BANG is a poor name for the event that gave rise to space, time, and all we observe — all we *can* observe, from the cosmic microwave background to the stars of our own galaxy. Nothing in the science of the Big Bang theory calls for the popular image of a gigantic cosmic explosion, say scientists. WMAP: NASA/WMAP SCIENCE TEAM; ABELL 2218 AND M100: NASA/ESA/STScI

1 If **distant galaxies** all are moving away from us, doesn't that mean we're at the **universe's center**?

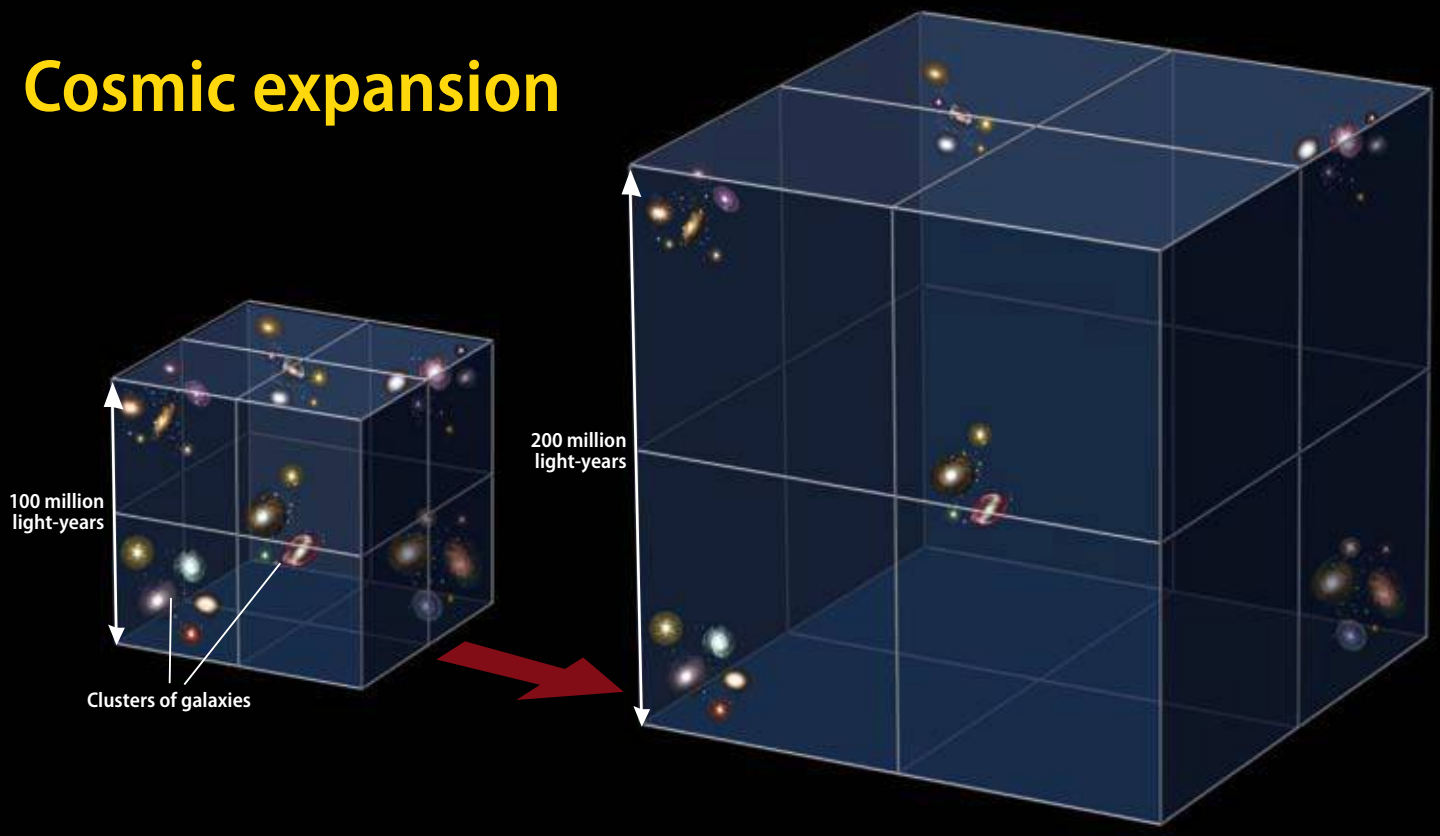
In a word, no.

In the 1920s, the work of Edwin Hubble and Milton Humason at California's Mount Wilson Observatory firmly established that all but the closest galaxies are moving away from us. Moreover, they saw a pattern — the more distant the galaxy, the faster it recedes. But this isn't motion through space. It's the systematic expansion of space itself, and it carries galaxies along for the ride.

In 1916, German theoretical physicist Albert Einstein published his general theory of relativity, which expanded on his earlier ideas by including how gravity affects the shape of space and the flow of time. A year later, Dutch astronomer

Liz Kruesi *studies astrophysics at Iowa State University.*

Cosmic expansion



EDWIN HUBBLE'S DISCOVERY of the expanding universe is one of the most fundamental in the history of astronomy. It's also frequently misrepresented. In this illustration, six clusters of galaxies in a cube 100 million light-years across separate from one another as the cube doubles in size. There is no expansion center. From the perspective of an observer in any galaxy cluster, the other clusters all appear to be moving away. This creates the illusion that each observer lies at the center of the expansion. *ASTRONOMY:* ROEN KELLY

Willem de Sitter used Einstein's equations to show that a nearly empty universe must also be an expanding one. Hubble understood the pattern he saw in receding galaxies was exactly what one would expect in a universe made of "de Sitter space."

Light traveling through expanding space becomes stretched out. Individual photons lose energy, so a given spectral line appears shifted toward longer (redder) wavelengths (see "Seeing the red limit," p. 40). But signals — like the explosion of a supernova — become stretched, too. Supernovae in distant galaxies last longer than they do in nearby galaxies — and the farther away they are, the longer they last. This means space is stretching, and the galaxies embedded in the underlying fabric of space follow the fabric's movement away from other objects.

Astronomers often use a balloon as an aid for picturing the expanding universe. Stickers on the balloon's surface represent galaxies, and, as the balloon inflates to represent the expansion of space, the distance between each sticker grows. Unfortunately, most people try to push the analogy too far and ask what's in the balloon's center.

Here's a two-dimensional experiment that gets to the heart of the matter. Draw many dots on a piece of paper. Now, make an enlarged copy as a transparency. Place the copy on the original, and pick one dot — any dot — to be the viewpoint. "Regardless of where the dot is, 'observers' in each dot will see other dots moving away," explains Asantha Cooray of the University of California, Irvine. "This is exactly what happens in the universe with each galaxy moving away from each other."

Another way to imagine cosmic expansion is to picture a loaf of raisin bread. As the bread (space) expands, each raisin (a galaxy) sees the other raisins receding from it. The raisins themselves don't change — the underlying structure does. And each raisin has an identical point of view: All other raisins are moving away from it. John Mather, a cosmologist and 2006 Nobel laureate at NASA's Goddard Space Flight Center, says, "Picture a full space that expands with everything in it."

Cosmologists assume that over sufficiently large distances — and we're talking scales larger than clusters of galaxies — the universe looks the same to an observer located anywhere within it. This is an extension of relativity, which says there's no preferred frame of reference for physical interactions. Scientists call this assumption the cosmological principle, and they test it regularly. So far, it appears to be a good approximation of the universe's state.

2 What is the **expanding universe** expanding into?

This is another question that comes from stretching that balloon analogy of the expanding universe too far. The universe is self-contained. As difficult as it is to believe, the universe can expand without expanding into something else.

Einstein's relativity provided a new way of looking at the universe. It pictures gravity not as a force, but as curves in space-time. Matter and energy in a gravitational field move the way curved space-time dictates. Relativity's space-warping behavior predicts that gravity bends light.

In 1919, a total solar eclipse gave scientists direct evidence. If massive objects warp space, light from a distant star would be displaced if the star's light passed close to a large mass, like the Sun. The effect is small, but, sure enough, astronomers observed changes in the positions of stars near the Sun during the eclipse.

This is but one of many validations of Einstein's theory. Relativity gives modern cosmology a solid foundation. As de Sitter showed, space is a dynamic entity that can warp, shrink, and grow without the necessity of being embedded in some higher-dimensional space.

3 What kind of **explosion** was the **Big Bang**?

The Big Bang wasn't *any* kind of explosion.

"There is nothing in the physics — in the science — of the Big Bang that talks about an explosion," says Charles Bennett, lead researcher on the Wilkinson Microwave Anisotropy Probe (WMAP) project. WMAP has produced our most precise picture of the cosmic microwave background (CMB). These photons have been traveling through space since electrons and protons first combined into atoms of neutral hydrogen, some 380,000 years after the universe's birth.

Astronomers know the universe is slightly bigger, cooler, and less dense than it was yesterday — this is the nature of cosmic expansion. If we extrapolate backward, then, in earlier days, the universe must have been smaller, hotter, and denser than astronomers now observe it to be.

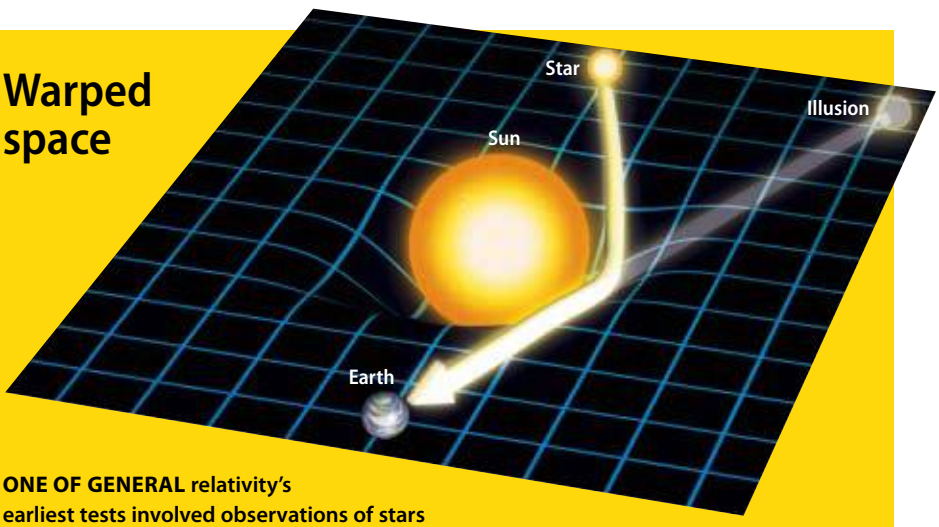
When the visible universe was half its present size, the density of matter was 8 times higher and the CMB was twice as hot. When the visible universe was 1/100 its present size, the CMB was 100 times hotter. When the visible universe was only a hundred millionth its present size, its temperature was 273 million kelvins above absolute zero. The density of cosmic matter was comparable to the air density at Earth's surface. These temperatures completely ionized the universe's gas into fast-moving protons and electrons.

"'Big Bang' is not an accurate name for the theory," Bennett explains. "What this theory describes is the expansion and the cooling of the universe. It doesn't describe an explosion at all."

But isn't the Big Bang an explosion in space? Its name implies a standard bang, such as a chemical explosion — think of fireworks — and once we have this image in our mind, it's hard to imagine the Big Bang as anything else. But the universe's beginning wasn't an explosion. It was closer to an unfolding, or creation, of matter, energy, time — and space itself.

"What would actually have been a much better name is the expanding-universe theory, because it's really a theory of how the universe expands," says David Spergel, a WMAP team member at Princeton University in New Jersey.

Warped space



ONE OF GENERAL relativity's earliest tests involved observations of stars during total solar eclipses. Starlight grazing the Sun, according to Einstein, bends as it follows space-time curved by the Sun's mass. Star positions measured near the eclipsed Sun appear slightly displaced from their actual positions. *ASTRONOMY:* ROEN KELLY

Hot stuff

The universe is expanding and cooling. It was smaller, hotter, and denser in the past — the basis of the Big Bang model.

13.7 billion years: The universe's age, give or take a few hundred million years.

93 billion light-years: This is the observable universe's present size.

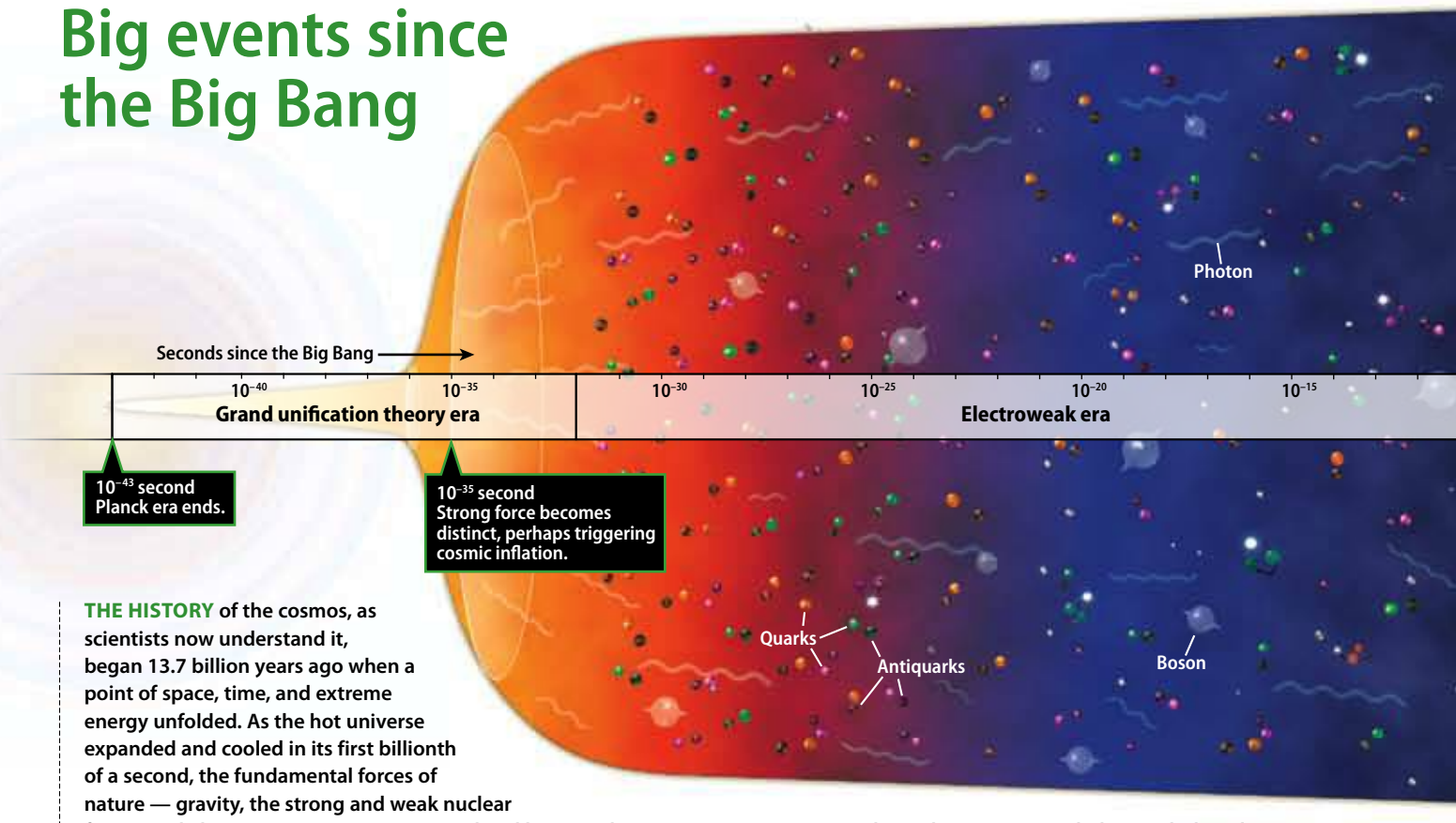
2.725 Kelvin: The average temperature of the cosmic microwave background (CMB).

4% The amount of ordinary matter — humans, planets, stars — the universe contains.

22% The amount of dark matter in the universe. This is an unidentified substance that interacts gravitationally with ordinary matter, but not with the other three fundamental forces (electromagnetism, and the weak and strong nuclear forces).

74% The amount of dark energy in the universe. Dark energy is an unidentified force that accelerates cosmic expansion.

Big events since the Big Bang



THE HISTORY of the cosmos, as scientists now understand it, began 13.7 billion years ago when a point of space, time, and extreme energy unfolded. As the hot universe expanded and cooled in its first billionth of a second, the fundamental forces of nature — gravity, the strong and weak nuclear forces, and electromagnetism — separated and became distinct. Next, subatomic particles appeared and, over the next 3 minutes, protons fused to make helium and a few other nuclei. About 380,000 years later, the universe cooled enough that electrons could bind with nuclei and make the first atoms. Photons flew free to make the cosmic microwave background (CMB). *ASTRONOMY:* ROEN KELLY

4 What came **before** the **Big Bang**?

No one knows. Maybe nothing existed before our universe or, says Harvard University's Avi Loeb, perhaps the universe "goes through cycles of Big Bangs. But there is no data to support one or the other hypothesis." Using the known laws of physics, cosmologists can extrapolate back to a fraction of a second (10^{-43}) after the Big Bang to the so-called Planck era, but there they must stop. Science simply cannot answer this question.

Scientists are stuck with two separate theories. One, quantum mechanics, explains the world of the very small, while the other, general relativity, explains the large-scale universe. Both work in their own regimes, but they are incompatible with each other. Says Loeb: "We need a theory that unifies quantum mechanics and gravity in order to extrapolate all the way back to the Big Bang."

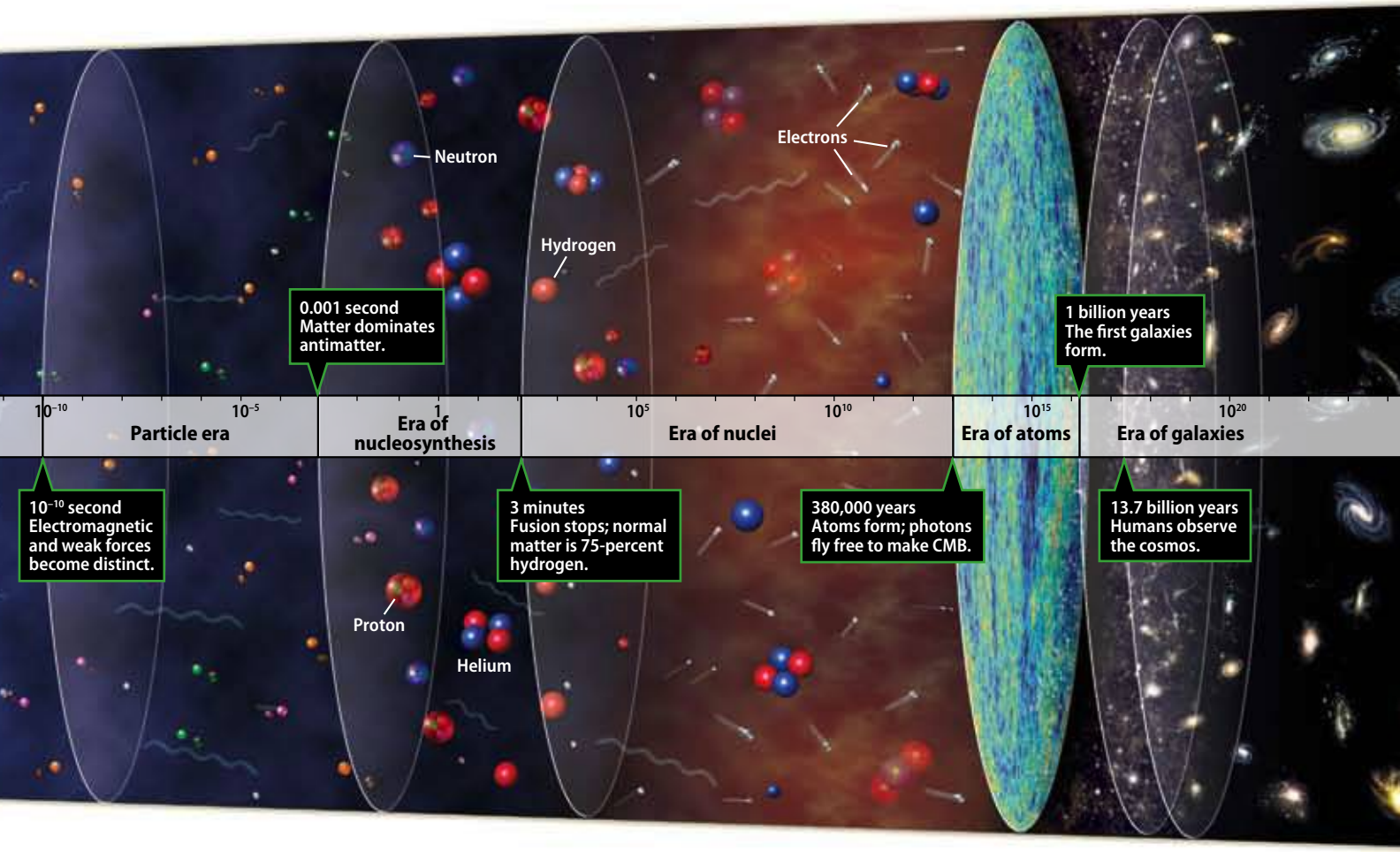
After centuries of research, physicists know there are four fundamental physical forces: gravity, electromagnetism, and the strong and weak nuclear forces. Theorists have unified electromagnetism and the weak force. When the universe was some 10 billionths of a second old, it became cool enough that this "electroweak" force separated into the two forces we now see.

Attempts to unify the strong and electroweak forces haven't yet met with success, but scientists believe that, even earlier in cosmic history, all of the fundamental forces were one. But gravity — so far, the domain of relativity — remains problematic.

Superstring theory attempts to unite relativity and quantum mechanics. In this view, all elementary particles are vibrating loops of energy called strings. Each type of string — whether it corresponds to an electron or a top quark — vibrates at a particular frequency.

Superstring theory has a testable consequence called supersymmetry, which posits the existence of unseen superpartners for every type of elementary particle known. The Large Hadron Collider (LHC) at the European Organization of Nuclear Research in Geneva, scheduled to begin

A MASSIVE EXPERIMENT section nears the end of a 10-hour descent into the Large Hadron Collider's cavern December 12, 2006. Physicists hope this and other detectors will provide evidence for supersymmetry. MAXIMILIEN BRICE/CERN



operations later this year, is expected to reach energies where it could prove or disprove supersymmetry.

5 What's **outside** the universe?

For all we know, the universe is infinite.

WMAP data verify earlier ideas that the universe experienced a hyperfast growth spurt cosmologists call inflation. So, it's likely the universe is much, much bigger than what we now observe.

It's useful to distinguish between the universe itself — everything that arose from the Big Bang — and the "observable universe" — everything we can detect. Cosmologists know the universe's age from observations of the cosmic microwave background: 13.7 billion years. And because light travels at a finite speed, observers on Earth can observe only light that has managed to reach us. Because we can see 13.7 billion light-years in any direction, the observable universe must be twice that size, right?

Wrong. The stuff we now see in the CMB emitted its light 13.7 billion years ago, but, since then, it condensed into galaxies, and, thanks to the expanding universe, those galaxies are now about 46.5 billion light-years away. So, the observable universe must be about 93 billion light-years across. Everyone knows Einstein's theory of relativity says light's speed is the ultimate speed limit for objects in space. But this doesn't apply to the expansion of space itself. The universal speed limit has a few exceptions in extreme cases — the universe's expansion is one of them.

The observable universe has an edge — scientists call it our horizon — bounded by the speed that light travels. What's on the other side? "As time goes on and the universe expands, more of the universe enters our horizon," explains Adam Riess of the Space Telescope Science Institute in Baltimore. Cosmologists say the universe beyond that which we can detect is "more of the same," he says.

Physical cosmology, a branch of science less than a century old, has brought forth some of its greatest successes in the past few years. These include pinning down the age of the cosmos and discovering that the universe is not only expanding, but its expansion is somehow accelerating. Yet cosmologists make no claim that our current model of the universe is complete. Saul Perlmutter of the Lawrence Berkeley Laboratory calls the Big Bang model "a working hypothesis … an amazingly successful first draft."

This is good — it would be a bit disappointing if we answered some of the biggest questions after such a short investigation. New detectors and experiments — both Earth-based, such as the Large Hadron Collider, and space-based, like WMAP's successor, Planck — will let scientists put what we think we know about the universe to the test. Is supersymmetry — and, by extension, string theory — for real? What fuels cosmic acceleration?

If the past is prologue, we should expect the unexpected.

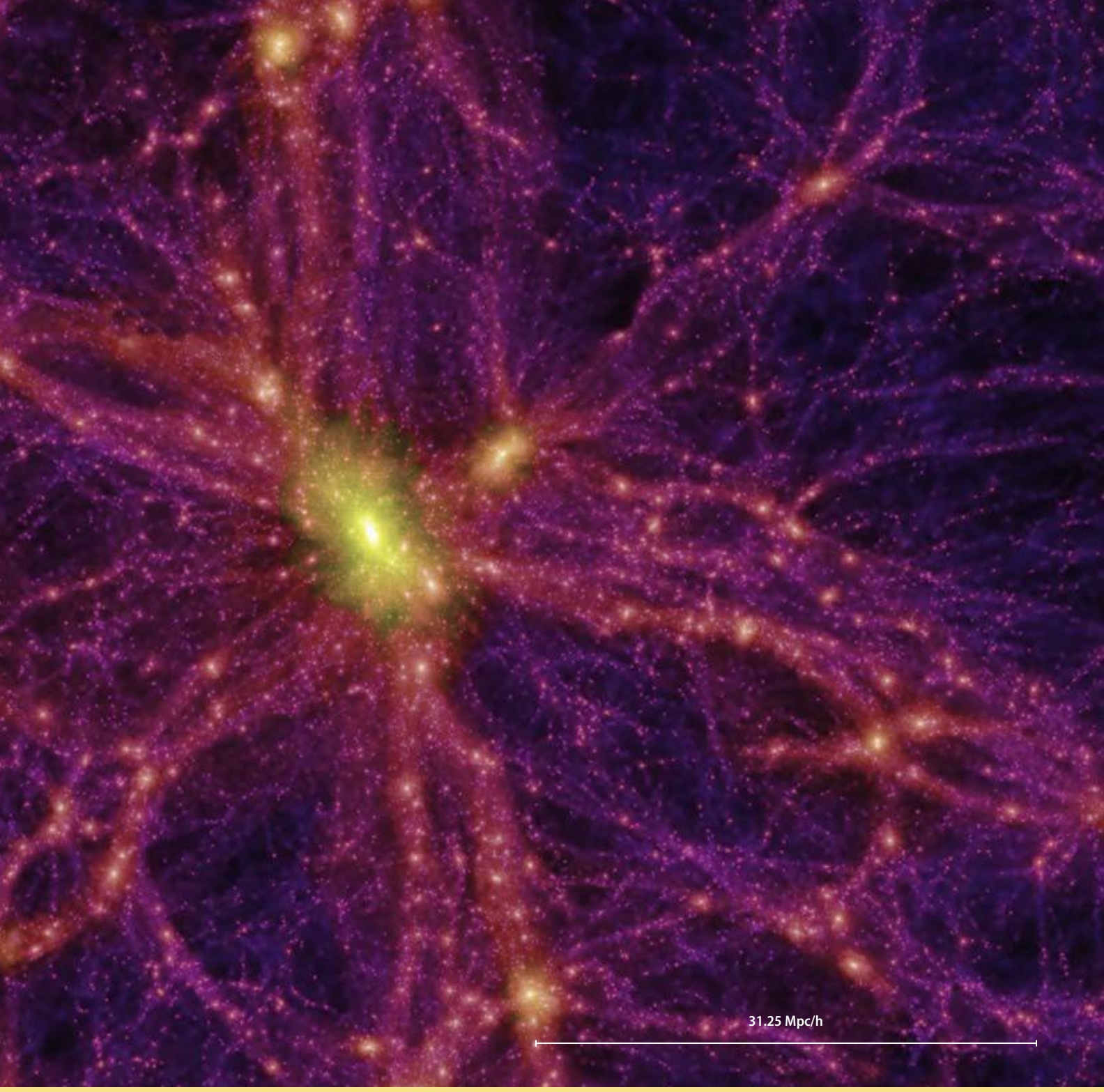
ONLINE EXTRA View movies that bring cosmic origins into sharper focus at www.astronomy.com/toc.

How to make 20 million galaxies

Astronomers transformed 25 terabytes of data into virtual galaxies to investigate cosmic evolution. /// BY STEVE NADIS

▲ **LARGE-SCALE STRUCTURE** appears as a delicately spun spider's web of dark matter in this image from the Millennium Run simulation. In the scale at bottom right, 31.25 megaparsecs corresponds to a distance of 102 million light-years.
ALL IMAGES: VIRGO CONSORTIUM/SPRINGEL ET AL.

◀ **DARK MATTER** surrounding this simulated galaxy cluster is depicted in color to show its distribution.



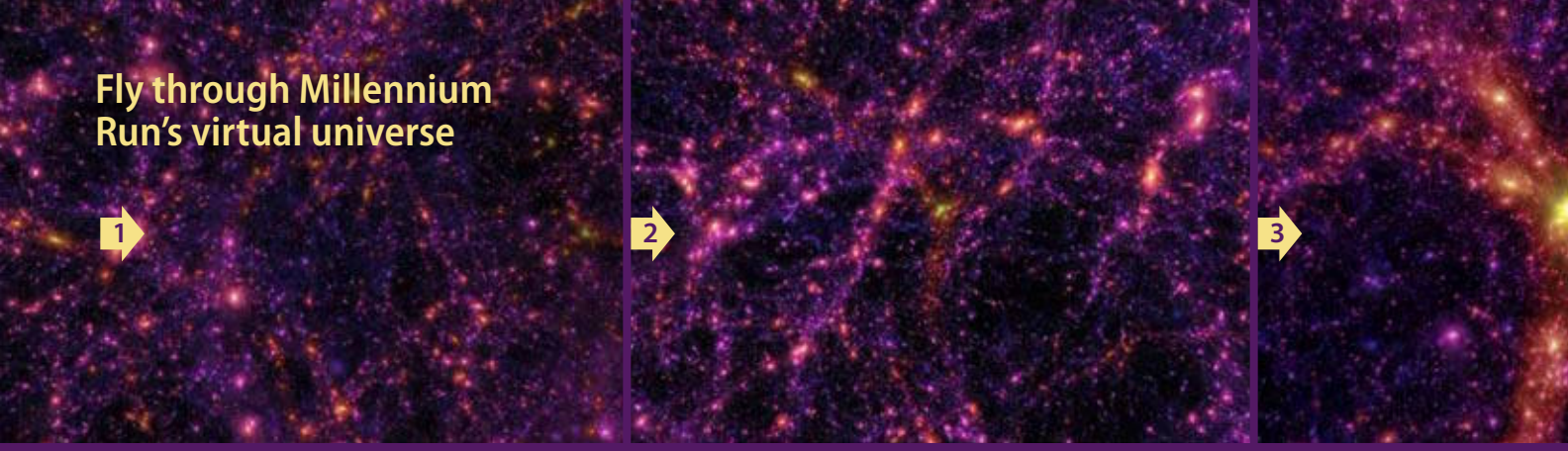
The computer-simulated story of our universe lies in an array of magnetic tapes and disk drives in Germany and England. No, your Aunt Sally's nasty divorce from Uncle Bob is not covered in this history, nor is the fall of the Roman Empire. This story is too big to cover mere earthlings. The drama unfolds within a cube, 2.2 billion light-years on a side, where some 20 million galaxies reveal their life stories.

This history, essentially, tells how particles came together to form the structure of the universe today. It covers cosmic evolution from about 10 million years after the Big Bang to the present.

Called the Millennium Run, this simulated view of the heavens — the most realistic simulation ever — is the product of the Virgo Consortium, an international group of astrophysicists dedicated to bringing state-of-the-art computing to the field of cosmology.

Millennium's 25-terabyte database is larger, in bit size, than the entire 120-million-item collection of the Library of Congress and roughly comparable to the projected yield of the Sloan Digital Sky Survey.

Unlike the data gathered by Sloan's Apache Point telescope, the Millennium output is not real, notes Consortium member Gus Evrard of the University of Michigan. "Nevertheless, the dataset is so rich, we haven't unearthed all the surprises



STRUCTURE EVOLVES from long, thin filaments into clumpy masses of galaxy-forming regions, say astronomers who created the universe in a computer. This series of images from the Millennium Run simulation depicts a virtual flight through this simulated universe.

lurking within. We can learn a lot from this mock database, mining it as if it were an actual sky survey."

Numerical simulations have become an indispensable part of the theorist's tool kit, as well as an essential complement to traditional observation and theory. The problems of structure formation and evolution are ones computers are particularly well-suited to tackle.

Cosmic microwave background measurements show the universe 400,000 years after the Big Bang. These measurements reveal subtle density fluctuations that seeded subsequent structure growth.

Today, the universe is a byzantine network of galaxies, clusters, filaments, sheets, and voids. The question is, what happened in between? How did the small density fluctuations observed at early times grow into the complex architecture of the "cosmic web" witnessed today?

"If we can understand how that happened, we can understand most of the age of the universe," says University of Chicago astrophysicist Andrey Kravtsov. Structures have continuously formed from the universe's earliest moments, even though galaxy formation didn't begin until several hundred million years later. Numerical simulations vividly fill the gap between the early universe's near-uniform conditions and the elaborate celestial scaffolding manifest today.

Probing structure's evolution

To track structure's evolution over time, computers followed the motions of billions of particles in the Millennium Run. The calculations themselves were "relatively trivial," says Millennium project leader Volker Springel of the Max Planck Institute for Astrophysics in Garching, Germany. "There's nothing you couldn't calculate with a paper and pencil, except that a supercomputer can perform a trillion of these operations a second."

These computational exercises test varying descriptions of the universe to find out which model best matches the views captured by telescopes. "We know how a single hydrogen atom interacts with a single photon," Evrard explains. "But if a whole bunch of photons interact with a cloud of mostly hydrogen, with a complex geometry and inhomogeneities, that immediately becomes a more complicated problem. And that's just a small-scale example of the kind of problem we face in cosmology."

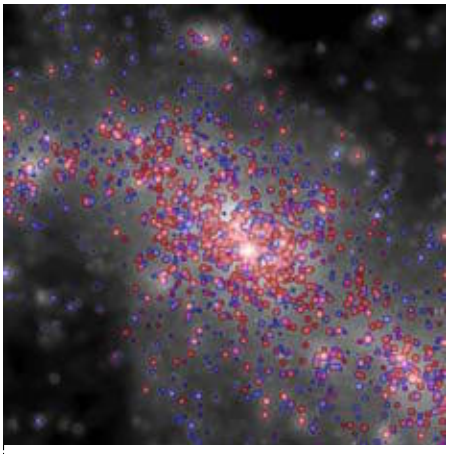
Using simulations to address questions about the universe's origin and structure is intellectually satisfying, as well as fun, says Evrard, who has compared the process to "playing in the sandbox." Nickolay Gnedin of Fermilab and the University of Chicago describes the practice in less humble terms: "It's like playing God on the computer." He and his associates get to set the knobs for the universe, switching things on and off at will, and then view the results on a cosmic scale.

Numerical simulations have grown in sophistication since the 1940s, when Swedish astronomer Erik Holmberg studied the clustering tendencies of galaxies with an analog computer consisting of an assortment of light bulbs and photocells. (Holmberg mimicked gravity, which obeys an inverse-square law, by exploiting the fact that light intensity also drops off with the square of distance.)

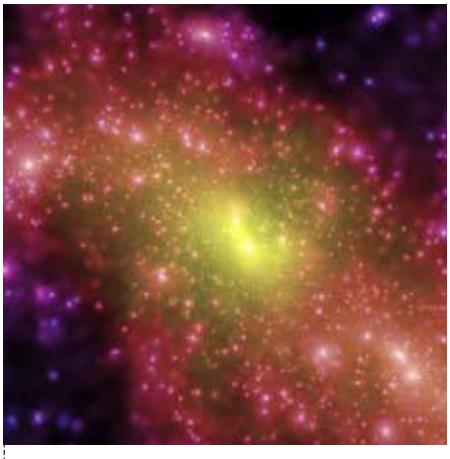
Building a better model

Scientists take two principal approaches when creating a detailed model of the universe with a computer: "n-body" simulations of "cold" dark-matter clumps that interact only through gravity, and "hydrodynamic"

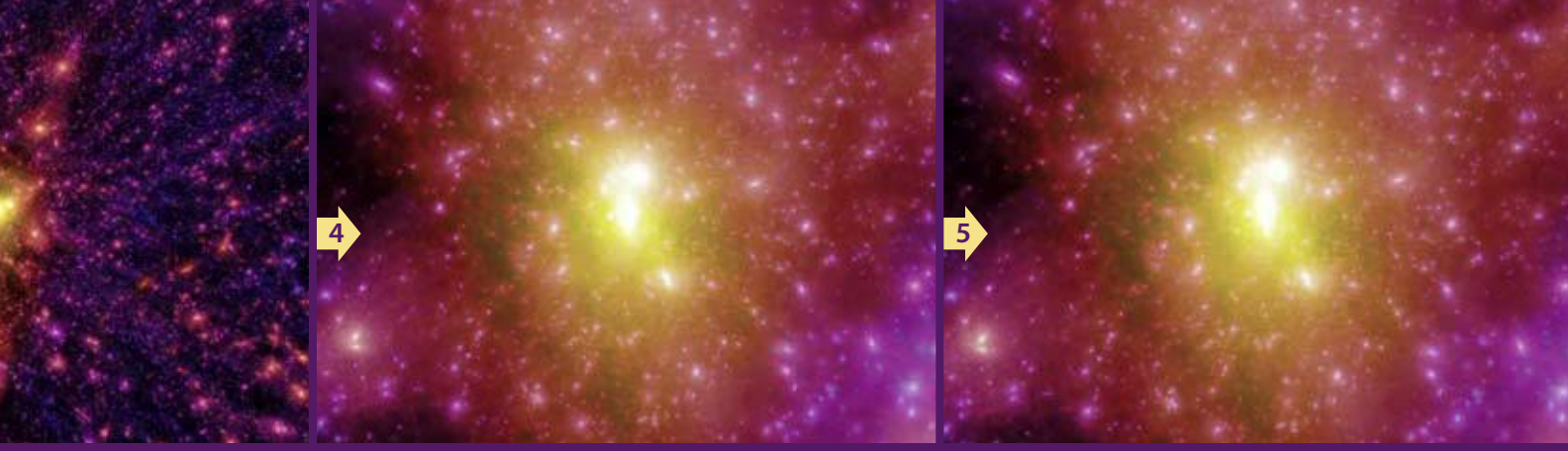
Steve Nadis *is an* Astronomy *contributing editor and science writer living in Cambridge, Massachusetts. He wrote about life in the universe in the November 2006 issue.*



GALAXIES CLUSTER in a tight knot near the center of this simulated image, showing their distribution.



DARK MATTER (pink) fills the spaces around tightly clustered galaxies in this Millennium Run simulation image.



Frames 1 and 2 show dark areas devoid of galaxies and structure forming along these filaments. Frame 3 shows a closer view of a clumpy galaxy cluster. Frames 4 and 5 show close-up views of the galaxy cluster shown in Frame 3. *— continued on next page*

simulations that track the behavior of ordinary matter, in addition to its invisible (or "dark") counterpart.

The first approach focuses exclusively on dark matter, although ordinary matter follows the dark stuff. In the so-called CDM approach, galaxies form in the densest parts of dark-matter clouds, or "halos."

The second approach brings luminous matter into the picture. This method involves more complicated calculations because there's not just gravity to contend with, but also shock waves, radiative cooling, turbulence, and magnetic fields. Says Springel, "Underlying it all is the basic, unanswered question: How do stars form?"

Ironically, says Gnedin, an enthusiast of hydrodynamic modeling, "At present, cosmologists can simulate dark matter, which we can't see, better than galaxies and gas, which we can." He believes the reason is that it's simple to model Newtonian gravity on a computer. This is why n-body simulations can cover large volumes of space, potentially encompassing the entire visible universe.

Even with ordinary gravity governing the proceedings, computational astrophysicists rely on shortcuts to simplify their physical models. The Millennium Run, for example, doesn't try to simulate the formation of individual stars. "Instead, we ask how much gas in the galaxy becomes available for star formation," Springel explains. Cosmologists estimate this quantity by measuring the galaxy's radiation output, which is a reflection of the total amount of gas cooling.

For now, Millennium stands as the biggest, most ambitious n-body simulation undertaken. Initial conditions, drawn from Sloan survey and Wilkinson Microwave Anisotropy Probe (WMAP) data, dictate the 10 billion dark-matter particles' distribution at the onset. The whole ensemble is then set free to interact gravitationally — drift, collide, or merge — with the equations of motion for every particle followed over time.

Simulations tell a story

What can be gained from such exercises? What can simulations offer that other techniques lack? "Whereas telescopes give us snapshots at different epochs, simulations allow us to take those snapshots and turn them into a coherent story," says David Weinberg, an astrophysicist at Ohio State University. You can watch objects form and evolve over time, playing the tape backward and forward to learn about the origins of objects like the Milky Way. "It's the difference between a slide show and a movie," Weinberg says.

The question of whether you can get more out of simulations than you put in is still contentious, Springel admits. "How many approximations can you make and still have predictive power?" he asks. "How can you simulate the formation of a galaxy with 100 billion stars when we can't even simulate the formation of a single star?" Nevertheless, Springel is confident the approximation he and his Virgo colleagues made is valid, at least to some degree. "The simulation provides a lot of predictive power about how the universe evolves, even without knowing how star formation proceeds," says Springel.

The analysis is ongoing. Astrophysicists generated more than a dozen publications based on the simulation's results in the year since the Millennium dataset was made public. So far, the simulation supports a "bottom-up," or hierarchical, picture of galaxy formation predicted by the cold-dark-matter (CDM) model. This finding reinforces the notion that galaxies start out small and grow through mergers to form larger ones.

The Sloan survey found a quasar 10 trillion times brighter than the Sun (suggesting a billion-solar-mass black hole lurking within), which formed just 850 million years after the Big Bang. Some researchers argued that an object becoming so massive so early was incompatible with the hierarchical-growth scenario implied by the CDM model. The Millennium Run showed, however, that distant quasars form naturally in a CDM scenario in numbers comparable to those Sloan turned up. "We didn't predict these early quasars or discover them," says Springel.

ASTRO TALK

BIG BANG
An event that created matter, space, and time; marks the beginning of space's rapid expansion.

COSMIC MICROWAVE RADIATION
Radiation found all over the sky with a temperature of 2.73 K. It is redshifted light emitted 380,000 years after the Big Bang.

DARK MATTER
An invisible substance that has mass but neither reflects nor emits light; detected by observing its gravitational effects on visible matter.

SLOAN DIGITAL SKY SURVEY (SDSS)
An astronomical survey that has imaged 200 million celestial objects spanning more than ¼ of the sky; analysis is ongoing.

— continued from previous page **Frame 6 shows a close-up view of a galaxy cluster surrounded by clouds of gas and dust. Frame 7 is a more distant view of the galaxy cluster shown in Frame 6. Frames 7 through 10 show increasingly distant views of the galaxy cluster as**

"But we showed that such objects are plausible, posing no apparent conflict with CDM. I don't think there's another way of getting such reassurance without a supercomputer simulation."

Nor, says Springel, would the "lambda-CDM" model — cold dark matter in an accelerating, dark-energy-dominated universe — ever have gained credence without simulations that showed how the cosmic "web" formed. This was something that could not be computed any other way. The resulting models depict a perfectly reasonable universe, he says, that mirrors structures seen in the sky.

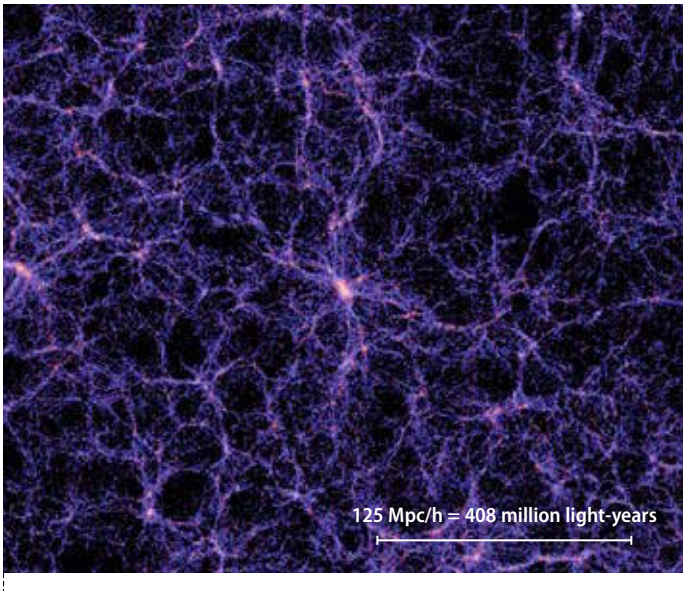
Of those structures, the largest identified to date is the "Sloan Great Wall" — a supercluster of more than 10,000 galaxies that spans more than 1.3 billion light-years. The Millennium Run revealed its own "Great Wall" of comparable size. This rare object is to be expected if the CDM model is right.

It's not simply a matter of taking the Millennium model and comparing it with data from Sloan and other surveys. "Since we can't read the answers we want strictly from the data, we use the simulations to interpret the observations and answer questions about the physics of the early universe," says Weinberg.

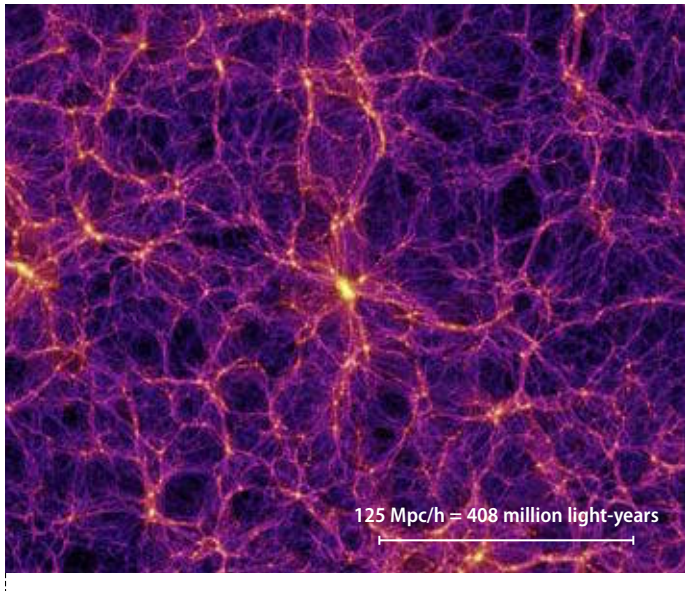
Simulations can also facilitate a survey's design, such as the upcoming Dark Energy Survey, by helping astronomers calibrate their approach. "You go in with an idea of what you want to achieve, and use simulations to see what the survey will actually deliver," says Evrard. "If you don't meet your objectives, you can figure out what more needs to be done." In addition, simulations can identify a survey's systematic errors, helping astronomers anticipate the likely rate of false detections of galaxy clusters or other objects.

So far, Evrard adds, "Simulations have demonstrated that the basic framework of large-scale structure formation is very solid. The challenge now is to really push the precision." The question is, "How sharp can we make the instrument?" says Evrard.

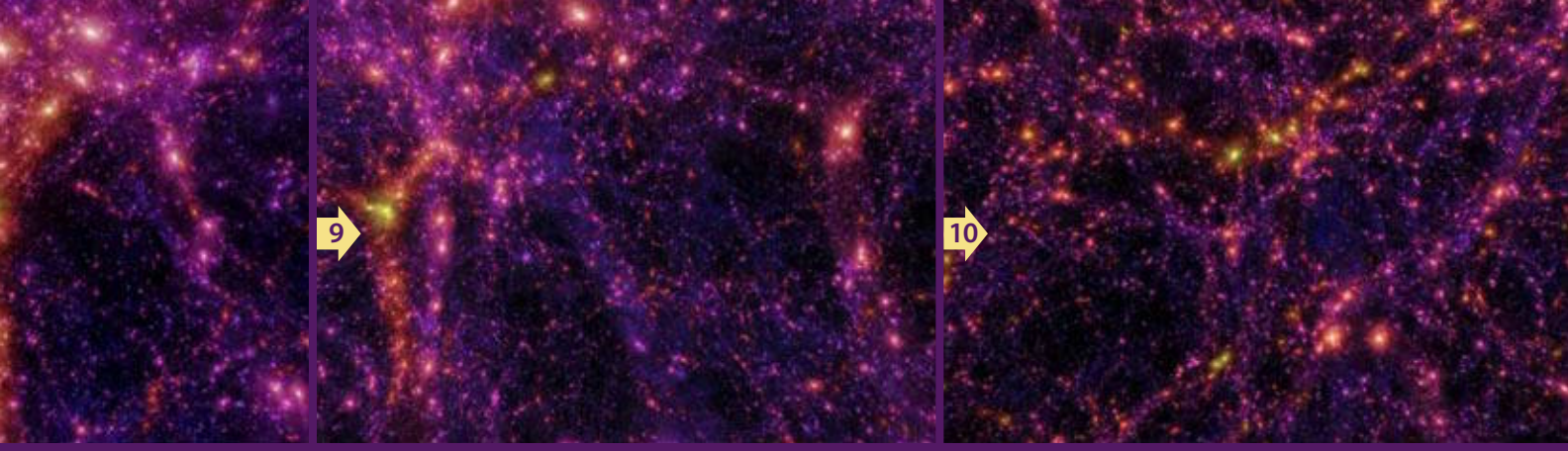
Accordingly, simulationists strive to boost the acuity of their simulations while astronomers simultaneously sharpen their measurements. Parity of this sort benefits astronomy. "If you can measure something precisely with your data but can't predict it accurately in your simulations, the precision of the data doesn't do you as much good," says Weinberg. Science advances most rapidly, argues Gnedin, when theory and observations are at the same level — when data can be used to constrain theory, and when theory is sufficiently advanced to explain the data.



SIMULATED GALAXIES lie in bright knots and dot the network of lines within the cosmic web in this image of large-scale light distribution created in the Millennium Run simulation.



DARK MATTER traces the same paths as galaxies, but in greater abundance, in this simulated image of the large-scale distribution of dark matter in the universe.



this flight through the Millennium Run's virtual universe comes to an end near where it began. Virgo Consortium astronomers started the computer simulation with 10 billion particles and ended up with 20 million galaxies within a cube 2.2 billion light-years per side.

In keeping with the trend toward greater detail, Springel will follow Millennium with a more detailed n-body simulation. Instead of picking a volume big enough to hold 20 million galaxies, he's putting a billion particles, or "resolving elements," into a single dark-matter halo containing one galaxy.

While this computational work is just beginning, Ben Moore at the University of Zurich has already discerned what might be the universe's very first structures — "mini-halos." Solar-system-sized mini-halos containing as much mass as Earth formed when the universe was just 20 million years old. Moore and his colleagues built a special supercomputer, called the Zbox, specifically for this calculation, which took 6 months of continuous number-crunching. The team started with a volume larger than a galaxy and zoomed into smaller and smaller regions, with ever-increasing resolution. In this scenario, the scientists assumed all dark matter consists of hypothetical elementary particles called neutralinos.

The discovery of the mini-halos came as a surprise. "We didn't expect objects to form so early," Moore says. "Previously, structure formation was assumed to occur on much larger scales of 100,000- to a million-solar-mass objects." Moore estimates our galaxy contains quadrillions of these mini-halos, which might be detected by spotting a close and fast-moving gamma-ray source.

Kravtsov is also pushing the resolution in his simulations, identifying the positions of individual galaxies inside dark-matter halos. Probing the connection between galaxies and halos, Kravtsov and his colleagues found that galaxies of different luminosities clustered differently when the universe was young than they do today. They also found that brighter galaxies reside in denser dark-matter structures.

After figuring out where galaxies form in halos, the next step for Kravtsov's team is to figure out what kinds of galaxies form in a given halo and how many stars they have. This is a problem that requires hydrodynamic simulations to solve.

Adding hydrodynamics to the mix

Gnedin, who's collaborating on this project, is convinced his field's future lies in hydrodynamics. In addition to performing the same n-body dark-matter calculations, this model requires monitoring the interactions of gas or ordinary matter. Although the calculations are more demanding, it is strictly a computational challenge, he says. "We can do Millennium Run-sized hydrodynamic simulations once computers are 20 to 30 times faster, which should be possible in less than a decade."

Others in the field, including Springel and Weinberg, are also moving toward hydrodynamic simulations. "People will go from looking at one galaxy at a time, or a few at a time, to tens, hundreds, and thousands, on up," Weinberg notes.

These efforts are part of a healthy competition between observers and theorists. Gnedin hopes that, "Armed with modern computing power, we theorists can keep up with the best observational advances — even though, in pure manpower, the observers outnumber us 3 to 1."

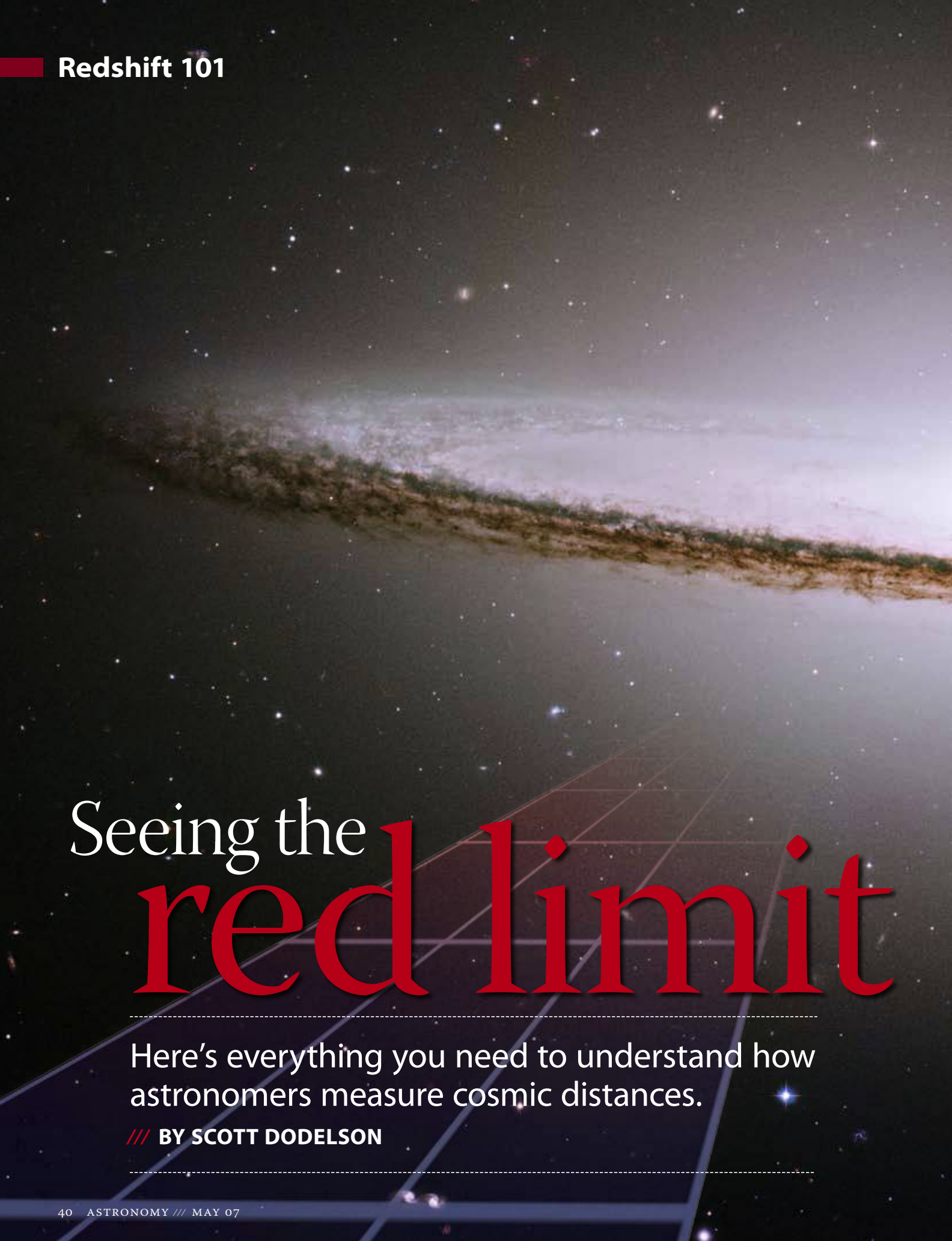
Keeping up with observational data, however, has proved difficult, especially in the face of recent increases in telescope size and an onslaught of data from surveys like Sloan, 2dF, 2MASS, and DEEP 2. Even if the simulationists could stay abreast of their telescopically inclined brethren, it's obvious that mock databases will never replace the real thing. "Because when the observers get it right, that's pretty much the end of the story," Evrard concedes. "The data won't change." On the other hand, mock databases like Millennium have a limited shelf life and are continually replaced by newer, more sophisticated simulations.

Evrard predicts that observers will eventually hit a wall: After building 98-foot (30 meters), and possibly 328-foot (100m), telescopes, it may become too expensive to erect ever-larger instruments. That would give computational astrophysicists a chance to catch up.

Progress will come not only through faster, more powerful computers, but also through better algorithms that will allow simulations involving a greater number of particles. In 1970, Princeton cosmologist James Peebles simulated galaxy clustering with only a few hundred particles. In 2005, Millennium raised the bar to 10 billion particles. Evrard expects that, "During our lifetimes, we should be able to do 100 billion billion particles, enough to represent every star in the universe."

While that number may seem far-fetched, 10-billion-particle demonstrations might have seemed equally preposterous just a few decades ago. And no one, certainly, was contemplating the next milestone — trillion-particle demonstrations — 60 years ago, when Erik Holmberg began simulating interactions between galaxies armed with just 200 light bulbs, not a single megabyte, and an uncanny sense of the direction in which his field needed to go.

ONLINE EXTRA Further explore the Millennium Run simulation at www.astronomy.com/toc.



Seeing the red limit

Here's everything you need to understand how astronomers measure cosmic distances.

/// BY SCOTT DODELSON

THE SOMBRERO GALAXY is moving away from us at 2.4 million mph (3.9 million km/h) thanks to the universe's expansion. In 1912, this was the first galaxy in which astronomers found a large redshift. NASA/ESA/STScI

The Sun is 8 light-minutes from Earth, the next nearest star is about 4 light-years away, and the center of our Milky Way Galaxy is more than 25,000 light-years away. For most people, these distances are unimaginable. For cosmologists, they're barely a walk around the block.

Our galaxy is but one of tens of millions astronomers have observed, and some of them are well over a billion light-years away. But, how do astronomers know this? Features in the spectra of distant galaxies appear at different wavelengths than those in closer galaxies. For distant galaxies, the shift is always in one direction — toward the red — and astronomers call this phenomenon "redshift." Objects moving away from us show redshifts, while those moving toward us show blueshifts. It turns out redshift is the key to unlocking the distant cosmos' mysteries.

Slipher and the Sombrero

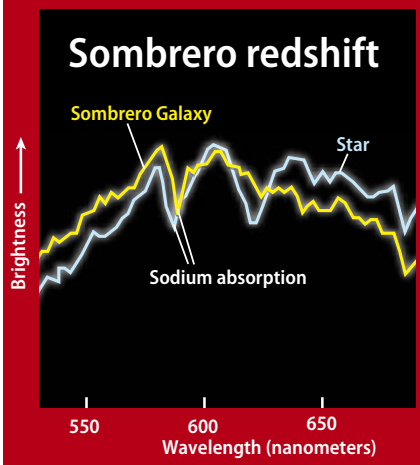
The first galaxy discovered with a large redshift was the Sombrero Galaxy (M104). Some of the light this galaxy emits is absorbed by atoms on its way out. The Sombrero, like most other galaxies, contains many neutral sodium atoms, which absorb light vibrating with a specific energy. So, when we observe M104's spectrum, we see a gap at precisely the energy corresponding to sodium's preferred energy.

In laboratories, scientists measure the wavelength sodium prefers — 589 nanometers (nm). So, astronomers would expect M104's spectrum to drop off at 589 nm.

In 1912, American astronomer Vesto Slipher at Lowell Observatory in Arizona took M104's spectrum using about 40 hours of telescope time. His spectrum shows the sodium absorption line not at 589 nm, but at the slightly longer wavelength of 591 nm.

What happened? The light from M104 has been "stretched" in wavelength — redshifted. Astronomers divide the expected wavelength by the observed wavelength, and then subtract 1 to get the redshift value (denoted as z). For M104, the result is 0.0034. Because z is positive, we know the Sombrero is moving away from us.

Between 1922 and 1929, Edwin Hubble and Milton Humason at Mount Wilson Observatory collected data showing that more distant galaxies have larger redshifts. This discovery remains the most direct evidence that the universe is expanding.



THE SAME SODIUM line occurs in different places in the spectra of Mu (μ) Ursae Majoris, a star in the Milky Way, and the Sombrero Galaxy (M104). The galaxy's spectral line appears shifted toward longer wavelengths. *ASTRONOMY:* ROEN KELLY

Hubble's Law

For small redshifts like M104's, the recession speed equals the speed of light multiplied by the redshift. So, the Sombrero Galaxy races away from us at 2.4 million mph (3.9 million km/h).

In 1929, Hubble reported that the redshifts of distant galaxies increase proportionally with their increasing distance. That is, the farther away a galaxy is, the faster it is moving away from us.

Imagine a baseball field that doubles in size every year. After one year, the pitcher's mound will be 121 feet (36.9 meters) from home plate. The mound, therefore, will be receding from home plate at 60.5 feet (18.4m) per year. A spot in center field that is originally 300 feet (91.4m) from home plate will be 600 feet (182.9m) away after. It recedes at 300 feet per year.

So it is in the cosmos. The farthest objects move away from us with the highest speeds, so they show the largest redshifts.

This so-called Hubble's Law assigns a distance to any cosmic object with a measured redshift. For redshifts much smaller than 0.5, a galaxy's distance equals 14 billion light-years times its redshift. Applying the Hubble formula to the Sombrero Galaxy with this value for the constant, we find the galaxy is almost 50 million light-years away.

Light doesn't travel to us instantly — it takes time. So, astronomers talk about "lookback times" — the time it takes an object's light to reach us. We can think of the Sun's lookback time as 8 minutes; for the center of our galaxy, it's about 25,000 years; and for M104, it's 50 million years.

Cosmological redshift tells us how far away an object is and how long ago the light we see was emitted. Redshift also pins down the universe's "scale factor" at the time a galaxy emitted its light.

Let's return to the baseball field that doubles in size every year. The scale factor today, when the pitcher's mound is 60.5 feet from home plate and the center fielder stands 300 feet away, equals 1. Following a year of expansion, the scale factor is 2. The physical distance between any two points on the baseball field is twice their original distance. That is, the new distance equals the initial distance times the scale factor.

The universe has stretched 1.0034 times since the light we see today from M104 left the galaxy. This means the scale factor when the light left M104 was 1/1.0034, or 99.7 percent. Such a large number means the universe hasn't expanded much while the light was traveling. Galaxies with larger redshifts are farther away from us, so light left them when the scale factor was smaller than it was for the Sombrero Galaxy.

A galaxy with a measured redshift gives astronomers a distance, a scale factor, and a lookback time. Now, when you hear an astronomer refer to "a galaxy at redshift 1," you can translate: The galaxy emitted its light at redshift 1, at a lookback time of 7.6 billion years ago, when the universe was half its present size at a scale factor of 0.5.

Defining distance

For objects with large redshifts, the simple distance formula explained above doesn't apply. In fact, the very notion of distance becomes ambiguous. Imagine putting down an infinitely long ruler at a fixed time and reading off the distance between us and a quasar at redshift 5.8. Place the ruler down today, and the distance is 27 billion light-years. (Astronomers call this the "co-moving distance.") Back when the quasar emitted this light, all distances were smaller by a factor of 6.8, so, at that time, the ruler would have shown 4 billion light-years.

Yet another way to measure distance is to "sit" on top of a photon and click off the

OBSERVATORIES OF THE CARNEGIE INSTITUTION OF WASHINGTON

EDWIN HUBBLE spotted a relationship between a galaxy's redshift and its distance. It was one of the 20th century's most important astronomical finds.

Scott Dodelson, *director of the Center for Particle Astrophysics at the Fermi National Accelerator Laboratory in Batavia, Illinois, wrote* Modern Cosmology *(Academic Press, 2003).*

miles as it travels toward us. The distance out to redshift 5.8 measured this way is 12.5 billion light-years.

Two important features of cosmic distances are changing the face of modern cosmology. First, they can be measured, which is remarkable in itself. And distances can teach us about how cosmic expansion has changed over time.

The distance to a given redshift depends on the universe's expansion speed. For nearby objects, the distance is inversely proportional to the Hubble constant, which measures how fast the universe is expanding today. This low-redshift formula (distance equals 14 billion light-years times z) assumes a particular value of the Hubble constant. If the Hubble constant were larger, then the Sombrero's distance would be smaller.

For objects at larger redshifts, the formula is more complicated, but the principle is the same. If the universe expanded rapidly in the past, then the scale factor increased rapidly, and light had a relatively small time to travel to us. So the distance to a given redshift is smaller if the universe expanded rapidly.

If we had some independent way of measuring distances, then, a table of distances vs. redshifts would tell us how fast the universe has expanded throughout history.

So, distances would matter if we could find a way to measure them without redshift. But what do astronomers do if they can't build a billion-light-year ruler?

Astronomers use the fact that objects far away from us appear dimmer than those that are closer. More quantitatively, the flux from an object is inversely proportional to the square of the distance between us. If we know the intrinsic luminosity of the object in question — say, because it is a "standard candle," a class of objects all with similar brightnesses — we can use the observed brightness to infer distance.

This standard astronomical gimmick works in cosmology only if astronomers define yet another distance — the "luminosity distance." This equals redshift plus 1 times the co-moving distance, and astronomers can compute it from the universe's expansion history. So, astronomers can use the observed brightness of a standard candle to infer a history of cosmic expansion.

The most celebrated objects for which astronomers have obtained luminosity distances are type Ia supernovae. This class of exploding stars is useful for two reasons. First, supernovae are among the brightest objects in the sky and can be detected at great distances. Second, type Ia supernovae serve as standard candles. Although they aren't equally bright, characteristics of these explosions — especially how rapidly they fade out — let astronomers infer how bright a given supernova actually is.

Starting in the mid-1990s, astronomers accumulated such information about a handful of distant supernovae. During the past decade, this number has ballooned to hundreds. The results are surprising: High-redshift type Ia supernovae are much fainter than scientists expected them to be. So, the luminosity distances are larger than expected, which corresponds to the fact that the young universe expanded more slowly than it does now. As the headlines proclaimed in 1998: The universe's expansion is accelerating.

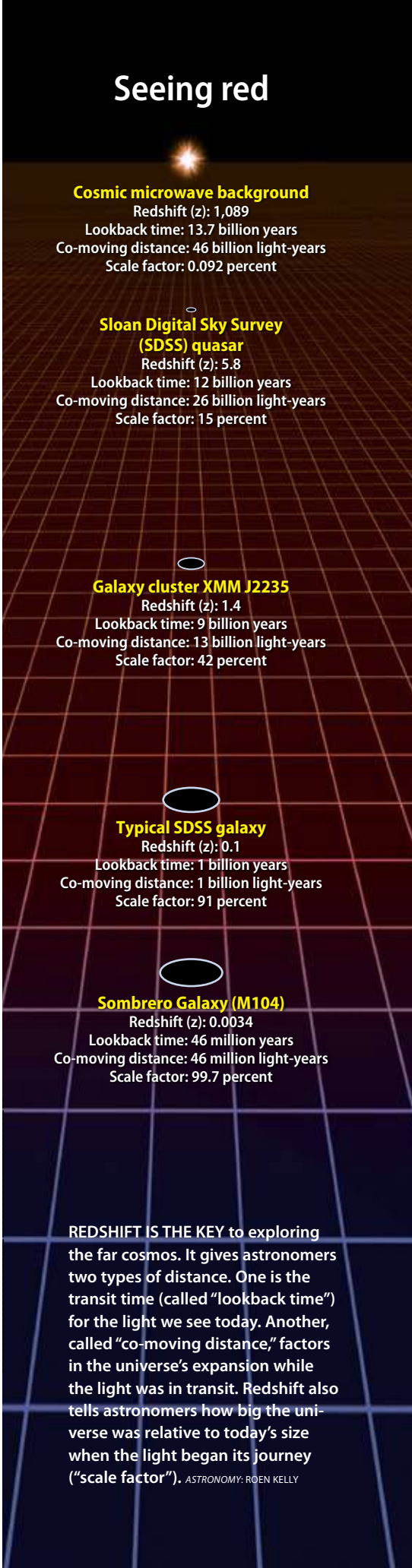
WHATEVER causes this acceleration, it's truly an exotic form of energy that isn't diluted as the volume enclosing it expands.

Ordinary matter — protons, neutrons, and even exotic dark matter — can't produce an accelerating universe. Imagine an expanding sphere enclosing 100 particles of matter. It becomes less dense as time goes on, and gravitational forces between the particles only slow the expansion.

Whatever causes this cosmic acceleration, it's truly an exotic form of energy that isn't diluted as the volume enclosing it expands. Physicists have dubbed this "dark energy." A major challenge of contemporary physics is to understand what dark energy is and how it fits into our theories of subatomic particles.

By probing the universe on the largest scales imaginable and measuring cosmic distances, astronomers have stumbled on the biggest mystery in fundamental physics. And it all began with redshift.

Seeing red


Cosmic microwave background
Redshift (z): 1,089
Lookback time: 13.7 billion years
Co-moving distance: 46 billion light-years
Scale factor: 0.092 percent
Sloan Digital Sky Survey (SDSS) quasar
Redshift (z): 5.8
Lookback time: 12 billion years
Co-moving distance: 26 billion light-years
Scale factor: 15 percent
Galaxy cluster XMM J2235
Redshift (z): 1.4
Lookback time: 9 billion years
Co-moving distance: 13 billion light-years
Scale factor: 42 percent
Typical SDSS galaxy
Redshift (z): 0.1
Lookback time: 1 billion years
Co-moving distance: 1 billion light-years
Scale factor: 91 percent
Sombrero Galaxy (M104)
Redshift (z): 0.0034
Lookback time: 46 million years
Co-moving distance: 46 million light-years
Scale factor: 99.7 percent

REDSHIFT IS THE KEY to exploring the far cosmos. It gives astronomers two types of distance. One is the transit time (called "lookback time") for the light we see today. Another, called "co-moving distance," factors in the universe's expansion while the light was in transit. Redshift also tells astronomers how big the universe was relative to today's size when the light began its journey ("scale factor"). *ASTRONOMY:* ROEN KELLY

BY MARTIN RATCLIFFE AND ALISTER LING

MAY 07

Mercury rises as Venus gleams

EARTHSHINE LETS us see the Moon's full disk when the Sun lights only a crescent. Start looking for blue-gray earthshine — light from Earth reflected off the Moon — after sunset May 18. TUNÇ TEZEL

Venus remains the highlight

of May evenings. The planet shines brilliantly above the western horizon and sets nearly 4 hours after the Sun. Mercury pops up for its best evening show this year. Saturn, high in the southwest at dusk, remains visible past midnight. Jupiter rises before Saturn sets, which makes a perfect excuse to grab a scope and do some planetary observing.

Hands down, **Mercury** puts on its best evening appearance of the year this month. On May 11, try spotting the planet 30 minutes after sunset a few degrees above the horizon. Mercury shines at magnitude –1.4 — rivaling Sirius, the brightest star in the sky — but evening twilight makes it a challenge. On May 16, now faded to magnitude –0.9, Mercury lies 7° north of Aldebaran in Taurus. Although Mercury spans just 6", a telescope may reveal its 77-percent-illuminated disk.

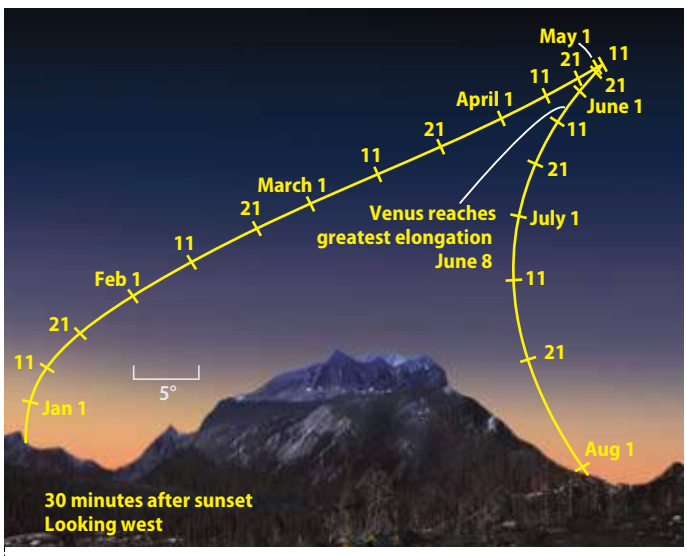
On the following night, May 17, a slender 1-day-old Moon passes 2.5° north of Mercury. Binoculars will show this best. By May 23, Mercury stands between the horns of Taurus the Bull and lies 8° above the horizon a full hour after sunset. In a dark sky, the planet glows at magnitude –0.3, and a scope will show Mercury illuminated only 58 percent. By sundown May 27, Mercury's sunlit portion drops below 50 percent. A telescope will reveal the planet as a tiny "half-moon."

On May 30, Mercury passes 1° north of the open star cluster M35 in Gemini. Setting 90 minutes after the Sun, the planet temporarily adds a magnitude 0.3 "star" to the constellation. Mercury outshines even Castor and Pollux, which seem to be watching this planetary

— *continued on page 49*

44 Venus at its best
49 Watch a comet's leftovers
49 Lunar crater Calippus
50 Mercury at its best
50 Two southern comets
51 Catch a naked-eye asteroid
51 A trapezoid of Saturn's moons

Visible to the naked eye
Visible with binoculars
Visible with a telescope



ASTRONOMY: ROEN KELLY

VENUS DAZZLES high in the evening sky and sets nearly 4 hours after the Sun. On June 8, Venus reaches its greatest angle from the Sun. After this, it spends the summer descending into twilight.

SPECIAL REPORT

On the trail of Comet McNaught

In January 2007, a surprise visitor from the distant Oort Cloud became the 21st century's first great comet. /// BY FRANCIS REDDY

As near as astronomers can reckon, Comet McNaught (C/2006 P1) fell toward the Sun for as long as 10 million years. The icy nugget began its fall where a trillion comets lie — out in the Oort Cloud, half a light-year or more from the Sun's fatal warmth. Eons ago, a passing star or molecular cloud probably provided the gravitational nudge that began what is likely the comet's first trip through the inner solar system.

On May 29, 2006, it rose north across the ecliptic between the orbits of Mars and Jupiter. But the new arrival went unnoticed until August 7. Then, Scottish astronomer Robert McNaught at Australia's Siding Spring Observatory imaged the comet using the 0.5-meter Uppsala Schmidt Telescope. At magnitude 17, the comet showed no sign its brief visit would be the least bit noteworthy.

But as Comet McNaught approached the Sun in early January 2007, it brightened rapidly and put on its best show for observers in the Northern Hemisphere. By January 11, it reached magnitude –3, outshining every star and planet except Venus. Despite its low altitude and the presence of bright twilight, the comet was obvious to many people who just happened to be outside after sunset.

And it only got better. Late on January 12, McNaught passed 15.9 million miles (25.5 million kilometers) from the Sun — less than half Mercury's distance. The next day, the comet brightened to magnitude –6 — so bright, it even outshone Venus. Observers who shielded the Sun from their eyes could see McNaught in broad daylight. With that, the comet took its place as the brightest comet since Ikeya-Seki in 1965.

After its swing around the Sun, the comet became an evening sight for Southern Hemisphere observers. As it pulled away from the Sun, McNaught faded quickly. But after January 17, as the comet rose higher out of evening twilight, a magnificent dust tail became apparent. Particles ejected from McNaught's icy nucleus during its close pass to the Sun created a broad, fan-shaped, striated glow that spanned 35° from the comet's head. Portions of the tail even were faintly visible to Northern Hemisphere observers, to the delight of skywatchers and astrophotographers around the globe.

Comet McNaught's brief appearance captivated millions, and many of those who gazed in wonder at it will be hooked on astronomy for life. But if the comet has, in some small way, changed us, we have also changed it. Thanks to the gravitational pull of the planets, the comet's passage through the inner solar system has reduced its period from millions of years to around 100,000. Until some future return, when the planets may give it a boost, the comet can never return home.

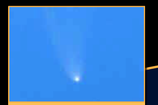
A great comet appears roughly once a decade. Comet McNaught arrived almost exactly 10 years after Comet Hale-Bopp. Although we don't yet know its name, the next great comet is already on its way. ■

Francis Reddy *is an associate editor of* Astronomy.

COMET McNAUGHT (C/2006 P1) was the brightest comet since 1965. Astronomer Robert McNaught discovered it August 7, 2006, but no one predicted its spectacular appearance. McNaught imaged his namesake January 20 from Australia's Siding Spring Observatory. ROBERT McNAUGHT/UNIV. OF ARIZONA/ANU/NASA/PHOTO RESEARCHERS, INC

THE VIEW IMPROVED as the comet pulled out of twilight and into a dark sky. This January 27 image from New Zealand shows the fading comet along with the Milky Way and the Small Magellanic Cloud. MINORU YONETO

McNAUGHT'S TAIL glowed in evening twilight long after the comet left northern skies. This is how the tails' aurora-like rays appeared near Wellington, Colorado, January 18. DAN AND MARY LASZLO



THE COMET SHONE in daylight January 14 following perihelion. ROB RATKOWSKI

THE COMET put on its best show for northern observers in the second week of January 2007. This January 10 view shows McNaught over Nuuk, the capital city of Greenland. LARS AND CASPER CHRISTIANSEN

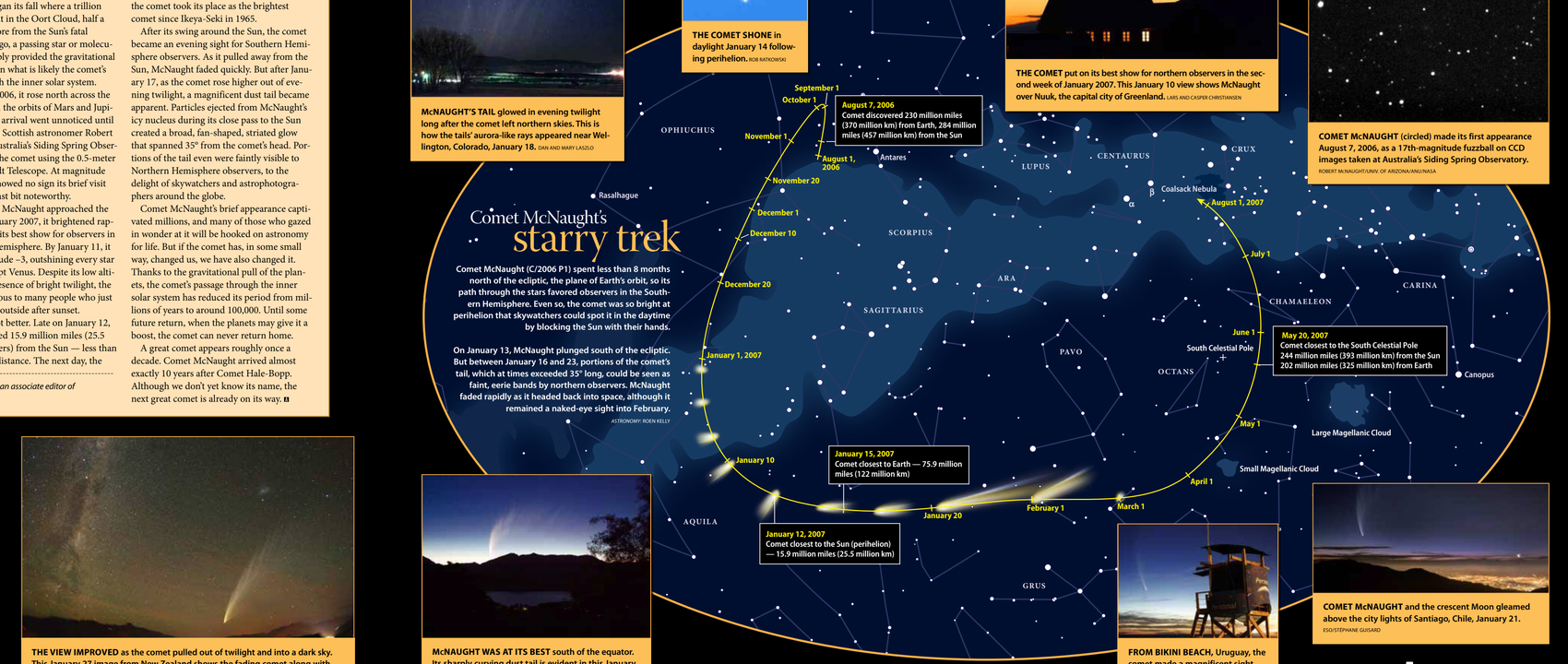
COMET McNAUGHT (circled) made its first appearance August 7, 2006, as a 17th-magnitude fuzzball on CCD images taken at Australia's Siding Spring Observatory. ROBERT McNAUGHT/UNIV. OF ARIZONA/ANU/NASA

Comet McNaught's starry trek

Comet McNaught (C/2006 P1) spent less than 8 months north of the ecliptic, the plane of Earth's orbit, so its path through the stars favored observers in the Southern Hemisphere. Even so, the comet was so bright at perihelion that skywatchers could spot it in the daytime by blocking the Sun with their hands.

On January 13, McNaught plunged south of the ecliptic. But between January 16 and 23, portions of the comet's tail, which at times exceeded 35° long, could be seen as faint, eerie bands by northern observers. McNaught faded rapidly as it headed back into space, although it remained a naked-eye sight into February.

ASTRONOMY: ROEN KELLY



McNAUGHT WAS AT ITS BEST south of the equator. Its sharply curving dust tail is evident in this January 18 image from Patagonia, Argentina. ROBERTO SOLANS

FROM BIKINI BEACH, Uruguay, the comet made a magnificent sight January 21. RODOLFO PÉREZ

COMET McNAUGHT and the crescent Moon gleamed above the city lights of Santiago, Chile, January 21. ESO/STEPHANE GUISARD

Astronomy magazine

COMET Q&A

An introduction to comets

Can't tell a coma from an Oort Cloud? Here's the place to start.

/// BY FRANCIS REDDY

GAS AND DUST released from a solid body just a few miles across create all of a comet's visible features. The gas and dust tails may span a hundred million miles.

What is a comet?

Comets are dark, solid bodies a few miles across. Scientists describe them as "dirty snowballs" containing a mixture of dust and frozen gases, like water and carbon dioxide.

Astronomers call a comet's solid part its nucleus. Some of the nucleus' icy material — perhaps less than 1 percent — evaporates as the comet nears the Sun. This creates an envelope of gas and dust that enshrouds the nucleus, preventing astronomers from seeing it up close.

This envelope, the coma, may extend 620,000 miles (1,000,000 km). The solar wind and radiation pressure from sunlight sweeps this material away from the nucleus and forms the comet's tails.

Comets usually have two tails. A gas, or ion, tail consists of ionized gases, glows faintly bluish, and points directly away from the Sun. Ejected comet dust usually creates a broader, brighter, curving, yellowish tail.

A comet's tails can span distances greater than that between Earth and the Sun. That such a small amount of material creates such large visible features has led some to describe comets as "the closest thing to nothing anything can be and still be something."

How do comets get their names?

A comet may carry the names of up to three independent discoverers. Increasingly, those discoverers are not individuals but automated observatories or solar-observing satellites.

Discoverers' names don't allow for a unique identification, so astronomers also assign comets an official catalog number. It begins with a one-letter prefix, usually a C for "comet" or a P for "periodic," followed by the discovery year and a single letter that indicates in which half of the month the discovery occurred. "A" represents January 1 though 15, "B" is January 16 through 31, for example.

Next, astronomers add a number representing the order of the comet's discovery during the period. This is why astronomers catalog Comet McNaught, the first comet discovered in the first half of August 2006, as C/2006 P1.

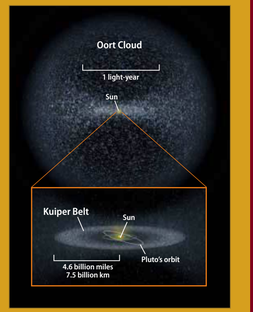
Something else happens when a comet's return becomes well established, either through a recovery or by observing a second passage through perihelion. These rare, periodic comets get a P prefix along with a unique number. So, astronomers officially designate Comet Halley, the first comet whose return was identified, as 1P/Halley.

Why are comet orbits so weird?

Astronomers think comets originate from two "cold storage" zones that surround the planetary system. The inner part of this comet cloud is a thick disk that begins near the orbit of Neptune and extends beyond the orbit of Pluto to about 50 times Earth's distance from the Sun. Often called the Kuiper Belt, this zone contains tens of thousands of objects larger than 62 miles (100 kilometers) across.

The Kuiper Belt lies within a much larger structure called the Oort Cloud. It forms a Sun-centered, spherical shell extending from the outer Kuiper Belt to more than a light-year into space. Astronomers think it contains a trillion objects.

Feeble gravitational disturbances from passing stars and interstellar gas clouds remove enough orbital energy from Oort Cloud comets that they begin their million-year-long falls toward the Sun. These long-period comets may arrive from any direction, with their highly elongated orbits randomly oriented to the paths of the planets. ¤



COMETS LIKE McNAUGHT come from the Oort Cloud, a shell of perhaps a trillion comets surrounding the Sun. The cloud spans more than a light-year. Inside it, at the planetary system's edge, lies the Kuiper Belt.

GALLERY

Space probes take comet close-ups

The first detailed views of comet nuclei show unexpected variety.

/// BY FRANCIS REDDY

AS A COMET NEARS THE Sun, its ice sublimates, turning from a solid directly into a gas. This transformation powers jets that launch gas and dust off the comet's nucleus and form its bright coma and tails. But it also shrouds the tiny nucleus from astronomers' prying eyes.

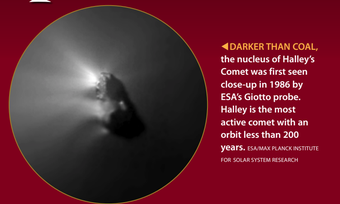
Scientists need space probes to penetrate a comet's glowing veil. The first was Giotto, the European Space Agency's (ESA) 1986 mission to 1P/Halley. Giotto passed 370 miles (596 kilometers) from the nucleus. Its images revealed an oblong body 9.5 by 4.5 miles (15.3 by 7.2 km) in size. Its surface is darker than coal.

In 2001, NASA's Deep Space 1 probe imaged bowling-pin-shaped 19P/Borrelly. NASA's Stardust mission flew within 149 miles (240 km) of 81P/Wild 2 on January 2, 2004. It captured samples of the comet's dust and returned them to Earth in 2006. On July 4, 2005, NASA's Deep Impact mission crashed a small spacecraft into 9P/Tempel 1. Before it hit, the impactor returned images that revealed features as small as 16 feet (5 meters).

These missions reveal that comets are more varied than scientists expected. The next mission to a comet, ESA's Rosetta, is already on its way to 67P/Churyumov-Gerasimenko. In May 2014, Rosetta will rendezvous with the comet, and, later that year, it will send a small lander to the surface. ¤

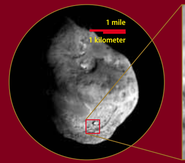
STARDUST RETURNED dust particles (circled) from Comet Wild 2's coma January 15, 2006. NASA/JPL

◀DARKER THAN COAL, the nucleus of Halley's Comet was first seen close-up in 1986 by ESA's Giotto probe. Halley is the most active comet with an orbit less than 200 years. ESA/MAX PLANCK INSTITUTE FOR SOLAR SYSTEM RESEARCH

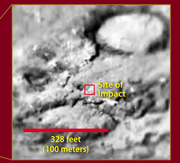


STARDUST REVEALED flat-bottomed craters, mesas, and spires on Comet Wild 2 January 2, 2004. NASA/JPL

NASA'S DEEP SPACE 1 flew within 1,370 miles (2,200 km) of 19P/Borrelly September 22, 2001. NASA/JPL



DEEP IMPACT'S PROBE imaged 9P/Tempel 1's nucleus in ever-greater detail as it rushed toward the surface July 4, 2005. NASA/JPL/UMD/FRANCIS REDDY



THE BEST-EVER VIEW of a comet's nucleus came to planetary scientists moments before the impactor struck. NASA/JPL/UMD/FRANCIS REDDY

HISTORIC COMETS

A century of great comets

Astronomy magazine

Comet McNaught joins an exclusive club of ghostly visitors.

/// BY FRANCIS REDDY

ABOUT ONCE A DECADE, on average, a comet appears so visually impressive astronomers rate it as a "great comet." Here's how a comet qualifies.

Earth passage. Even modestly active comets like Hyakutake (1996) or1P/Halley (1910) can put on great displays if they happen to pass close enough to Earth.

Activity. When a comet nears the Sun, its icy surface vaporizes and throws off large amounts of gas and dust. This activity creates the enormous tails that make comets appear so striking. All comets undergo this sort of activity — some more, some less — but an unusually active comet like Hale-Bopp (1997) can put on a terrific show, even if it doesn't pass particularly close to Earth or the Sun.

Sun passage. Because the Sun's heat activates a comet's icy surface, a close solar approach can make an otherwise humdrum comet shine brightly. The more dust a comet ejects, the more visually striking it can be. A close pass by the Sun actually cracked the nuclei of comets Ikeya-Seki (1965) and West (1976) to pieces. This freed up a lot of dust that formed naked-eye tails more than 30° long. ¤

▲ BOTH ITS ACTIVITY and its close passage to the Sun contributed to Comet McNaught's greatness. DAVE CURTIS

Comet McNaught

C/2006 P1

Discovered: August 7, 2006

Brightest: Magnitude (mag.) –6 on January 13, 2007

Closest to Sun: 15.9 million miles (25.5 million km), January 12, 2007

Closest to Earth: 75.9 million miles (122 million km), January 15, 2007

▶ THIS DIAGRAM SHOWS the positions of the planets when Comet McNaught passed closest to Earth January 15, 2007. ALL DIAGRAMS: ASTRONOMY: ROEN KELLY

▲ HALE-BOPP'S unusually active nucleus made a great comet despite its large distances from Earth and the Sun. This diagram shows Hale-Bopp's closest approach to Earth March 22, 1997.

Comet Hale-Bopp

C/1995 O1

Discovered: July 23, 1995

Brightest: Mag. –0.7 on March 26, 1997

Closest to Sun: 84.6 million miles (136 million km), April 1, 1997

Closest to Earth: 122.7 million miles (197 million km), March 22, 1997

▲ COMET HALE-BOPP may have been the most active comet since 1577. Its broad, curving dust tail made it stand out even in light-polluted suburban skies. RON LUXEMBURG

Comet Hyakutake

C/1996 B2

Discovered: January 30, 1996

Brightest: Mag. 1 on April 20, 1996

Closest to Sun: 21.4 million miles (34 million km), May 1, 1996

Closest to Earth: 9.3 million miles (15 million km), March 25, 1996

▲ HYAKUTAKE PRODUCED little dust, but thanks to the comet's close sweep past Earth, observers saw a bluish gas tail that stretched 100° or more. BILL AND SALLY FLETCHER

▲ COMET HYAKUTAKE made one of the closest Earth passes of any comet known March 25, 1996 — just 53 days after astronomers found it.

Comet West

C/1975 V1

Discovered: November 5, 1975

Brightest: Mag. –1 on March 1, 1976

Closest to Sun: 18.6 million miles (30 million km), February 25, 1976

Closest to Earth: 73.4 million miles (118 million km), February 29, 1976

▲ COMET WEST split into four pieces when it rounded the Sun and produced a beautiful tail that spanned 30° March 8, 1976. RONALD ROYER AND STEVE PADILLA

▶ THE FRAGMENTS OF Comet West passed closest to Earth February 29, 1976.

Comet Ikeya-Seki

C/1965 S1

Discovered: September 18, 1965

Brightest: Mag. –10 on October 21, 1965

Closest to Sun: 743,600 miles (1.2 million km), October 21, 1965

Closest to Earth: 84.6 million miles (136 million km), October 17, 1965

▲ LIKE A GHOSTLY scimitar, Ikeya-Seki rose tail-first into the morning sky a week after perihelion. The comet's twisted, rope-like tail was a spectacular sight that reached 30° in length. SMITHSONIAN ASTROPHYSICAL OBSERVATORY

▲ IKEYA-SEKI PASSED 84.6 million miles from Earth October 17, 1965. Four days later, the comet sped to within a million miles of the Sun and fragmented into at least three pieces.

▲ TELESCOPIC OBSERVERS monitored Comet Bennett for spiral structures created by the nucleus' dusty jets. LPL/UNIV. OF ARIZONA

▶ COMET BENNETT PASSED only 22 percent closer to the Sun than it did Earth.

Comet Bennett

C/1969 Y1

Discovered: December 28, 1969

Brightest: Mag. 0 on March 20, 1970

Closest to Sun: 50.1 million miles (81 million km), March 20, 1970

Closest to Earth: 64.1 million miles (103 million km), March 26, 1970

Comet Skjellerup-Maristany

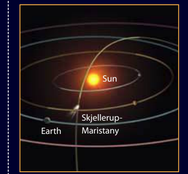
C/1927 X1

Discovered: November 27, 1927

Brightest: Mag. –6 on December 18, 1927

Closest to Sun: 16.7 million miles (27 million km), December 18, 1927

Closest to Earth: 69.7 million miles (112 million km), December 12, 1927



▲ COMET SKJELLERUP-MARISTANY could be seen in daylight at perihelion December 18. At the end of the month, observers reported a tail stretching 40° long. The comet passed closest to Earth December 12, 1927.

Great January Comet

C/1910 A1

Discovered: January 13, 1910

Brightest: Mag. –5 on January 17, 1910

Closest to Sun: 12 million miles (19 million km), January 17, 1910

Closest to Earth: 79.9 million miles (129 million km), January 18, 1910

◀ VISUAL OBSERVERS found the Great January Comet just before it rounded the Sun. The comet soon outshone Venus and was visible during the day. But it didn't pass unusually close to the Sun or Earth.

Comet 1P/Halley

Discovered: Historical; first comet predicted to return

Brightest: Mag. 0 on May 20, 1910

Closest to Sun: 54.8 million miles (88 million km), April 20, 1910

Closest to Earth: 13.9 million miles (22 million km), May 20, 1910

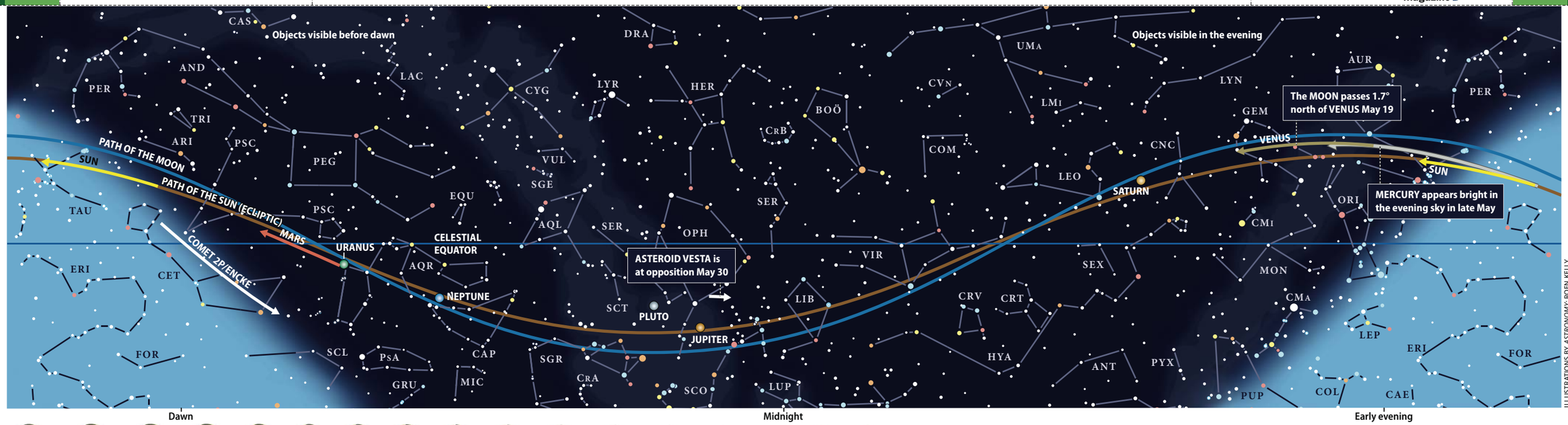
▲ COMET HALLEY IS the only comet with an orbit less than 200 years that ranks as a great comet. This close-up of Halley's coma was taken through the 60-inch reflector at Mount Wilson Observatory. MT. WILSON AND LAS CAMPANAS OBSERVATORIES

▲ HALLEY BRUSHED Earth a month after perihelion in 1910.

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine



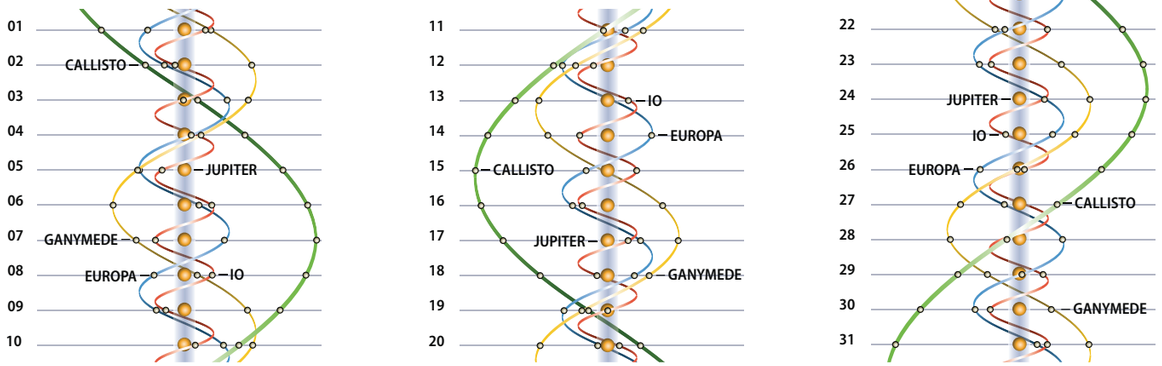
ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	• PLUTO
Date	May 15	May 31	May 15	May 15	May 15	May 15	May 15	May 15	May 15
Magnitude	–1.1	0.2	–4.2	0.9	–2.5	0.4	5.9	7.9	13.9
Angular size	5.6"	7.7"	18.3"	5.5"	45.0"	18.0"	3.4"	2.3"	0.1"
Illumination	83%	42%	62%	90%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.195	0.870	0.910	1.706	4.386	9.243	20.485	29.999	30.453
Distance (AU) from Sun	0.319	0.404	0.720	1.385	5.326	9.209	20.091	30.048	31.284
Right ascension (2000.0)	4h20.4m	6h09.7m	6h32.3m	0h00.4m	17h05.7m	9h25.8m	23h16.9m	21h37.4m	17h53.3m
Declination (2000.0)	23°13'	25°23'	25°54'	–1°36'	–22°07'	16°28'	–5°27'	–14°27'	–16°23'

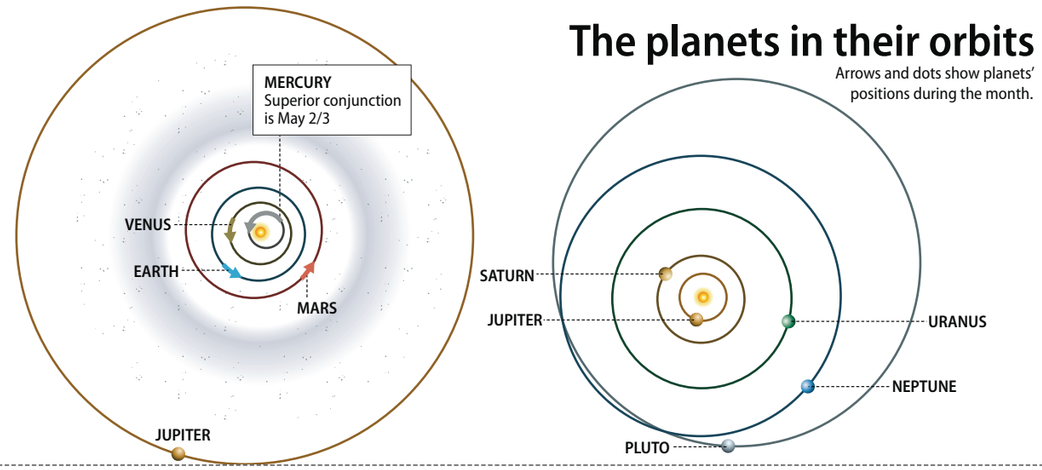
Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EDT on date shown. South is at top to match the view through a telescope.



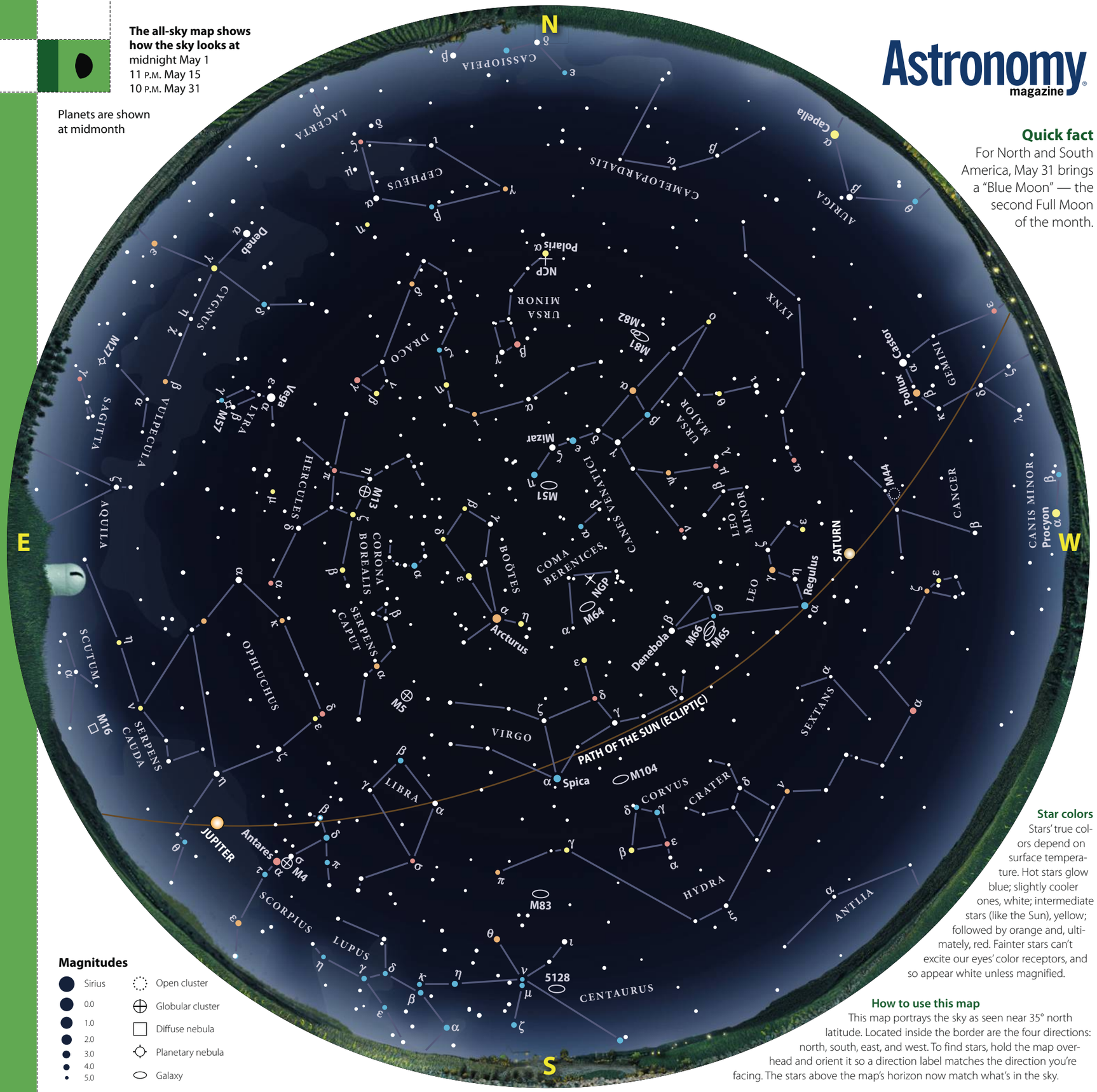
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
midnight May 1
11 P.M. May 15
10 P.M. May 31

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Astronomy magazine

Quick fact
For North and South America, May 31 brings a "Blue Moon" — the second Full Moon of the month.

Star colors
Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map
This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

may 07

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		[01]	[02]	[03]	[04]	[05]
[06]	[07]	[08]	[09]	[10]	[11]	[12]
[13]	[14]	[15]	[16]	[17]	[18]	[19]
[20]	[21]	[22]	[23]	[24]	[25]	[26]
[27]	[28]	[29]	[30]	[31]		

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

02 Full Moon occurs at 6:09 A.M. EDT

Mercury is in superior conjunction, midnight EDT

04 The Moon passes 0.5° south of Antares, 2 P.M. EDT

05 Eta Aquarid meteor shower peaks

The Moon passes 6° south of Jupiter, 8 A.M. EDT

10 Last Quarter Moon occurs at 12:27 A.M. EDT

The Moon passes 1.8° south of Neptune, 4 A.M. EDT

12 The Moon passes 1.3° north of Uranus, 3 A.M. EDT

The Moon passes 3° north of Mars, 9 P.M. EDT

15 The Moon is at perigee (223,315 miles from Earth), 11:06 A.M. EDT

16 New Moon occurs at 3:27 P.M. EDT

17 The Moon passes 3° north of Mercury, 8 P.M. EDT

19 The Moon passes 1.7° north of Venus, 9 P.M. EDT

22 The Moon passes 0.8° north of Saturn, 3 P.M. EDT

23 The Moon passes 0.7° north of Regulus, noon EDT

First Quarter Moon occurs at 5:03 P.M. EDT

27 The Moon is at apogee (251,941 miles from Earth), 6:02 P.M. EDT

30 Asteroid Vesta is at opposition, 10 A.M. EDT

31 The Moon passes 0.4° south of Antares, 9 P.M. EDT

Full Moon occurs at 9:04 P.M. EDT

ONLINE EXTRA For definitions of terms, visit www.astronomy.com/glossary.

— *continued from page 44*

interloper. The planet remains visible through the first week of June.

Venus sparkles like a diamond high above Mercury's position. The planet appears so bright because its global cloud layer reflects 60 percent of the sunlight striking it. And while Venus looks disarmingly lovely, the planet's clouds form out of sulfuric-acid droplets, not water as on Earth.

During May, Venus shows a gibbous phase that shrinks from night to night. On May 1, the planet shines at magnitude –4.1 and displays a 16"-wide, 68-percent illuminated disk — features clearly observable in small scopes. By May 19, Venus' sunlit portion shrinks to 60 percent, but, to compensate, the disk grows by 2". At month's end, Venus is 21" across with a 55-percent-illuminated disk.

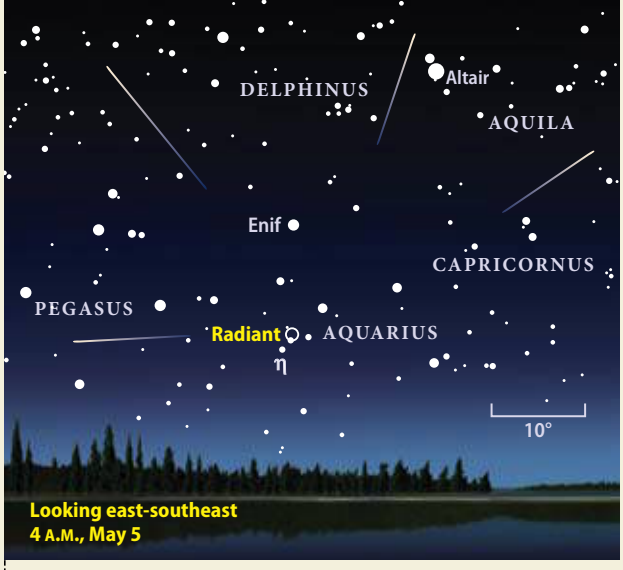
For an observing challenge, try to spot the moment when you think Venus' phase reaches exactly 50 percent — a "half-moon." Astronomers predict this should occur in early June as the planet reaches its largest angle east of the Sun (greatest eastern elongation).

Look with binoculars May 9 for a nice view of Venus 1.7° north of the faint star cluster M35. Ten days later, the crescent Moon pairs up with the planet and passes just 1° north of Venus. This stunning arrangement occurs frequently enough, but this month's steep ecliptic angle lifts the pair high above the northwestern horizon until well after dark. (This same effect also makes Mercury excel.) Venus wanders across central Gemini for the remainder of May and ends the month 4° south of Pollux.

While Venus arcs high above the horizon, the background stars sliding behind it carry Leo the Lion and its planetary resident, **Saturn**, steadily westward. As the month opens, Saturn stands high in the south at sunset. But by June, the ringed planet lies just 24° from Venus in the western sky.

Saturn shines at magnitude 0.4 on May 1, and it really stands out near the faint stars of Cancer the Crab. Saturn

Martin Ratcliffe *is the former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*



ASTRONOMY: ROEN KELLY

TIDBITS FROM HALLEY'S COMET burn up in Earth's atmosphere this month. The Eta Aquarid meteor shower peaks May 5, but a bright Moon dims prospects.

WATCH COMET HALLEY'S LEFTOVERS

This year's Eta Aquarid meteor shower is heavily affected by the waning gibbous Moon, which is just past full phase. The shower, which is active from April 21 through May 12, peaks May 5. This year, the early part of the show in April occurs under more favorable observing conditions than the peak.

The shower's radiant lies near the Water Jar asterism in the constellation Aquarius, which rises about 2 hours before twilight begins. Still, May's warm weather makes the Eta Aquarids one of the year's best-observed showers.

The number of meteors observed depends on the radiant's altitude. From the Northern Hemisphere, the radiant stands nearly 20° high in the east-southeast by 4 A.M. local daylight time. The shower actually favors Southern Hemisphere observers. There, the radiant rises to nearly 60°. From a dark, moonless, Northern Hemisphere site, observers can see a meteor every few minutes at the shower's peak.

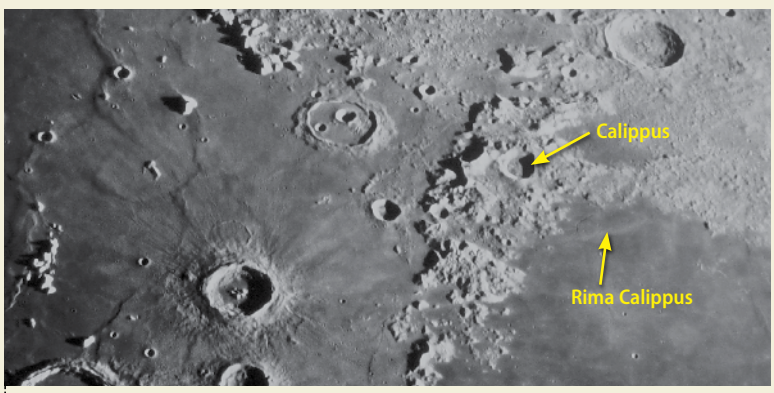
The comet debris that gives rise to the shower comes from Comet 1P/Halley, the first comet whose return astronomers predicted. Halley's dust also produces October's Orionid shower, which favors northern observers. This year, a waxing gibbous Moon interferes with this shower as well.

CALIPPUS OF THE CAUCASUS

Within the Moon's Caucasus Mountains on Mare Imbrium's eastern border lies the 20-mile-wide crater Calippus. Its irregular walls slump inside the crater's western side, and the crater floor appears lumpy.

Nearby is another form of lunar indentation called either a rille (from a German word for "groove") or rima (from a Latin term for "fissure"). Rima Calippus is a rille system that lies southeast of the crater, near a swell of hardened lava on the "shore" of Mare Serenitatis. Steep walls and flat bottoms characterize rilles.

Both of these features named for the ancient Greek astronomer Calippus are best viewed when low-angled lighting creates long shadows. This month, the Sun sets over the region May 8 and rises again May 24.

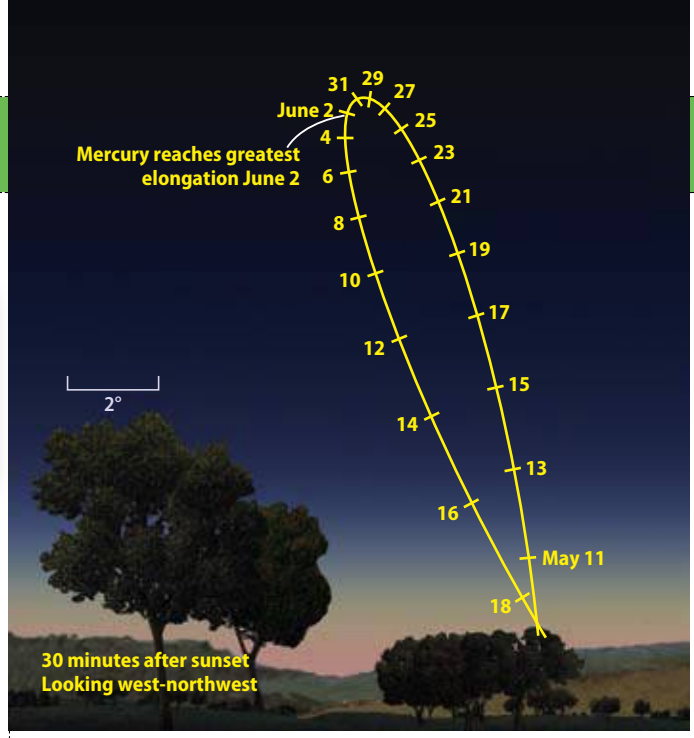


CONSOLIDATED LUNAR ATLAS (UA/LPI)

CALIPPUS CRATER takes its name from the Greek astronomer Calippus. Observe this rugged region at low Sun angles for the best views.

/// WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Jupiter (southeast)	Mars (southeast)
Venus (west)	Saturn (west)	Jupiter (west)
Jupiter (southeast)		
Saturn (southwest)		



ASTRONOMY: ROEN KELLY

WATCH MERCURY'S BEST evening performance build during the month. The elusive planet climbs highest into the sky in late May and early June and then descends quickly into twilight.

actually remains in Leo the Lion. Its retrograde loop over, Saturn now begins creeping toward Regulus. The planet is moving farther away. By month's end, Saturn lies 883 million miles from Earth. But this change doesn't significantly change the planet's brightness.

The rings tilt 15° to our line of sight with Saturn, which gives them an angular extent of 41" by 11". By comparison, Saturn's disk spans 18". The brightest ring, B, is clearly visible in a small telescope. The B ring is sandwiched between the outer, slightly fainter A ring, and the dim, inner C, or Crepe, ring.

You'll find Saturn 3.6° west of a 6-day-old crescent Moon May 22. Look through your scope to find Titan lying due east of the planet, in line with the rings' long axis. Titan is easy to spot just about any night because it's fairly bright at magnitude 8.4. It circuits the planet every 16 days, and it's the easiest saturnian moon to track down.

Tethys and Enceladus hug the planet's southern side, while Dione and Rhea hover tightly to the northeast. These moons are much fainter than Titan and glow between magnitudes 9.7 and 11.5. Because they lie closer to the planet, they also orbit around Saturn in less time than Titan, so their positions vary significantly from night to night.

Iapetus was brightest April 13, after reaching its greatest western elongation, so during May it slowly fades. Saturn's distant moon is turning its darker face earthward. For the first 4 days of May, Iapetus lies fairly close to the planet at magnitude 11.1, which makes it easier to spot than Enceladus. Later in May, Iapetus moves farther east of the planet and continues its fade-out. On May 7, Titan and Iapetus lie less than 1' apart on the planet's east side.

Jupiter rises at 11:30 P.M. local time May 1 and two hours earlier by the month's end. Jupiter's arc through the sky keeps it near the horizon, so the planet is best viewed when it lies due south, which occurs around 3 A.M. local time as May opens.

Jupiter's path against the background stars of Ophiuchus carries the giant planet westward throughout May. During the month, Jupiter slides toward Antares, the brightest star in the neighboring constellation of Scorpius.

Jupiter is brilliant and reaches magnitude –2.6 by the end of May. Grab any telescope, and, with a magnification of only 30 times, you can spot the brightest jovian moons. Io, the innermost of these, orbits Jupiter every 1.8 days, while Callisto, the outermost large moon, takes more than a couple of weeks. Europa and Ganymede circle the planet between them. These four bright satellites create ever-changing patterns for telescopic observers.

Jupiter's disk spans 46" by month's end. It exhibits features

COMETS ENCKE AND McNAUGHT GLOW DOWN UNDER

2P/Encke. During the past few months, Comet Encke has been a decent sight for observers in the Northern Hemisphere. The comet passed its perihelion April 19 and swept into the morning sky, where it now puts on a good display for observers in the Southern Hemisphere.

Look to the east an hour before sunrise, and scan with binoculars up toward Beta (β) Ceti. Encke will likely put on a better show now than before it rounded the Sun. The comet brightens after maximum heating, and it should show a more prominent tail.

C/2006 P1 (McNaught). Comet McNaught is now a dim fuzzball arcing through the southern sky. As it rounded the Sun January 12, the comet brightened to magnitude –6, which made it the brightest comet in 4 decades. Its grand post-perihelion performance, reserved for Southern Hemisphere observers, has become the stuff of astronomical legend.

This month, the 13th-magnitude comet skirts the South Celestial Pole. It passes closest May 20 (see the finder chart on page 58). Comet McNaught remains visible all night long from most of the Southern Hemisphere. Viewing this fuzzy, pale "star" through the eyepiece, it'll be hard to imagine it once sported a tail that stretched 35° across the sky.

Take the time to look closely at this surprise visitor before it disappears from view. Does even a hint of a tail remain? Is the comet's head, or coma, elongated? Keep an eye on McNaught's changes as the comet heads back into the depths of space. It won't be back for another 100,000 years.

CATCH VESTA: A NAKED-EYE ASTEROID

It's pretty cool to see unusual objects without a telescope, whether it's a galaxy like M31 or M33, a variable star, or a normally telescopic planet like Uranus. This month, you can add an asteroid to this list.

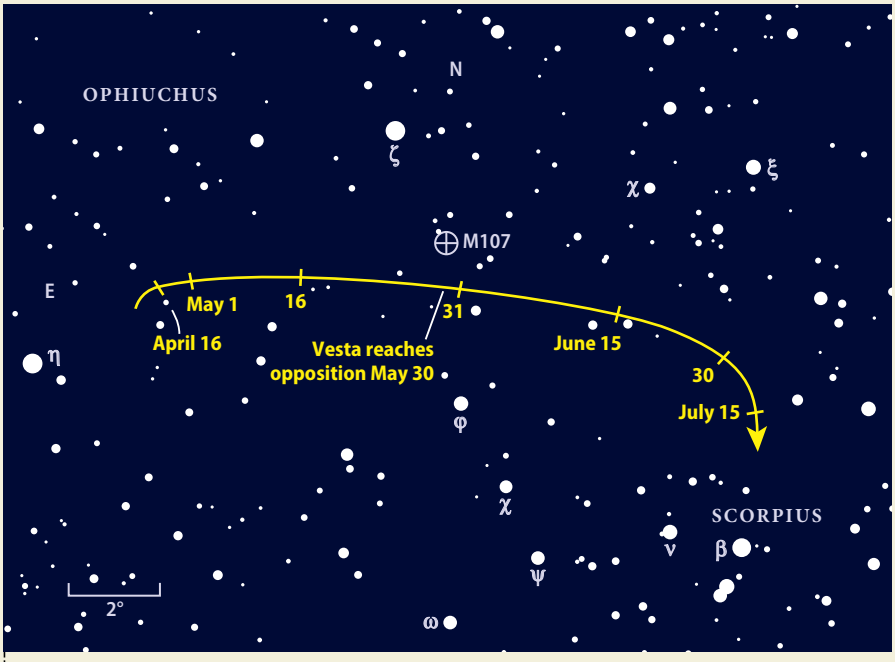
Like most main-belt asteroids, 4 Vesta follows an eccentric, or out-of-round, orbit. Every 3.6 years, Vesta reaches perihelion, its closest point to the Sun.

On May 30, Vesta is headed toward perihelion. On that day, the asteroid also reaches opposition — it's as close to Earth as it can get. These factors favorably combine to make Vesta glow at magnitude 5.4. At nearly a full magnitude brighter than usual, Vesta becomes a naked-eye target.

Vesta lies in the outer fringes of Ophiuchus, so observers won't have to contend with crowded Milky Way star fields. In fact, as Vesta cruises south of the line from bright Zeta (ζ) Ophiuchi to Eta (η), there's only one 6th-magnitude star in the entire zone.

First, try locating Vesta without binoculars. Look around midnight, when the asteroid reaches its highest altitude.

The standard approach to identifying asteroids is observing the field different nights to make sure the suspect moves.



VESTA BRIGHTENS to naked-eye status this month. It should be an easy binocular target. Look one-third of the way from Eta (η) Ophiuchi to Zeta (ζ).

Because 4 Vesta is so bright, observers on its trail can confirm their success using binoculars in a single night.

Vesta doesn't drop below 6th magnitude, the naked-eye limit, until the end of June. So, try to find it every time you're under dark skies.

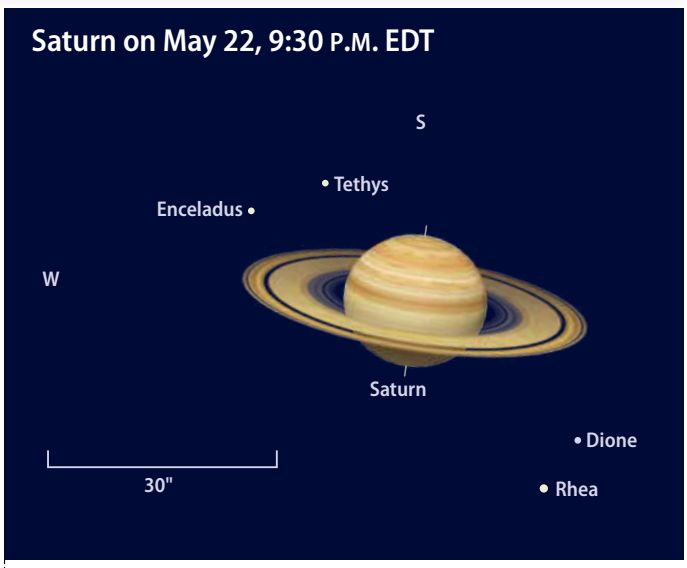
Heinrich Olbers found Vesta, the fourth asteroid discovered, March 29, 1807. What a way to celebrate Vesta's 200th year!

such as dark and bright spots, wave-like features called festoons that extend away from the equatorial cloud belts, and the famous Great Red Spot (GRS). Beginning in mid-2006, though, the GRS was no longer alone. One of the planet's previously white ovals turned red. Dubbed Red Spot, Jr., this newcomer now rivals the GRS' ruddy hue. Resist the temptation to boost the magnification too high. Jupiter's low altitude means its light is passing through a thicker portion of Earth's atmosphere, so the image won't be satisfying.

The dwarf-planet **Pluto** wanders far from the ecliptic, where the major planets reside. It lies in northwestern Sagittarius following a number of years in Serpens and Ophiuchus. Pluto lies due west of the Omega Nebula (M17) at the following distances: 6° 21' (May 1); 6° 36' (May 15); and 6° 58' (May 31). If you know your field of view, you can center on M17 and scan west to Pluto. Alternatively, use the fine open cluster M23 to locate Pluto.

On May 1, the planet lies 2.7° north of the cluster. Pluto is faint at magnitude 13.9 and requires at least an 8-inch scope under excellent skies to spot visually.

Mars rises in the eastern sky at about 4:30 A.M. May 1, shining like a 1st-magnitude star. However, the sky is already beginning to brighten with the encroaching dawn. If you have a clear enough horizon, try also to spot **Uranus**, 1.7° west of Mars, and within a Moon's width of Phi (ϕ) Aquarii. By the end of May, Mars rises an hour earlier, offering about an hour of dark sky. But Mars remains tiny, its 6"-wide disk revealing little to backyard scopes.



SATURN'S LARGE ICY moons Tethys, Dione, and Rhea are easy to locate May 22. Observers will find them surrounding the planet, forming a trapezoid pattern with Enceladus.

Uranus is an interesting target this year. Hubble images clearly show the leading hemisphere to be brighter than the following hemisphere. Larger amateur scopes may reveal this difference visually. You'll easily find the planet shining at magnitude 5.9 near Phi Aquarii. This is slightly fainter than a star in the same field of view, 96 Aquarii.

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Why buy a telescope from a website that sells pots and pans, hammocks, sunglasses, and radar detectors in addition to telescopes? If you want a real telescope, don't go to a department store. Go to a *real* telescope store.

A hot new 92mm TMB triplet apo refractor joins the *2007 Hot Product* TMB-130 triplet!

TMB 130 triplet apo **$3999**

Sky & Telescope named the **TMB Optical TMB-130** 130mm f/7 triplet a *Hot Product for 2007* because this superb apochromatic refractor is available now! There is no multi-year waiting list for the $3999 TMB-130, as you will find with some other premium-grade optics. And owner comments on *Cloudy Nights* have been spectacular!

And now the TMB-130 is joined by the new $1999 **TMB-92** – a compact 92mm f/5.5 triplet apo designed to fill the void left by the discontinued Astro-Physics Stowaway (a legendary scope that sells for as much as $6000 on the used market).

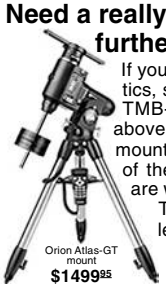
Both the TMB-130 and TMB-92, created by renowned optics designer Thomas M. Back, use premium FPL-53 ED glass in their fully multicoated air-spaced apochromatic triplet lens optical systems.

They have premium features in addition to their premium optics – like a collimatable temperature-compensated lens cell and a *FeatherTouch* dual-speed rotating rack and pinion focuser (3.5" on the TMB-130, 2.7" on the TMB-92) for 35mm, CCD, and medium format photography. They are available now and they are priced right!

TMB 92 triplet apo **$1999**

And coming soon – the **TMB-80**, an 80mm f/6.3 triplet apo for less than $1000! It's the first time a TMB-quality scope has been available at such an attractive price!

Need a really good go-to mount for your TMB? Look no further than a Losmandy, Orion, or Vixen.



Orion Atlas-GT mount **$1499.95**

If you have top-quality optics, such as a TMB-92 or TMB-130 apo refractor, above, a great equatorial mount will get the most out of them. These mounts are well worth a look.

The **Orion Atlas-GT**, left, has a good 40 lb. payload capacity that will carry your optics nicely for only $1499.95. You can train its computer to find objects with 1 arc minute accuracy!

The new $2699 heavy-duty **Vixen Sphinx-D**, right, has a big 50 lb. payload capacity and the latest version of the famous Starbook hand control with a full-color sky map on its LCD screen. You simply click on an object's icon on the map to go right to it.

Vixen Sphinx-D go-to mount with Starbook LCD screen controller **$2699**

Losmandy G11GT Gemini go-to mount **$3195**

The Losmandy **G11GT** with Gemini go-to controller, left, has a 60 lb. payload capacity for $3195. It has been the favorite mount of serious astrophotographers for years.

Your car's back seat will hold a 16" Meade LightBridge.

Meade 16" f/4.5 LightBridge **$1999**

The **Meade LightBridge Dobsonians** – all of them named *Sky & Telescope Hot Products for 2007* – use a truss-tube design that lets you break down even the largest 16" model into a few small packages that fit comfortably into the back seat of most compact cars.

All Meade LightBridge Dobsonian reflectors have a smooth 2" machined aluminum Crayford-style focuser with a separate 1.25" eyepiece holder; a 2" 26mm QX eyepiece with a very wide 70° field of view, and an illuminated wide field non-magnifying red dot-type finder with four different reticle patterns.

Steel roller bearings in the base provide smooth hitch-free azimuth motion at the touch of a finger. Altitude tension is adjustable. A battery-operated fan on the metal primary mirror cell assures fast cooling of the diffraction-limited BK7 optical glass mirror. No tools are needed to assemble and break down each Meade LightBridge in the field.

The prices below include shipping from Meade.

8" f/6 LightBridge **$599**
10" f/5 LightBridge **799**
12" f/5 LightBridge **999**
16" f/4.5 LightBridge **1999**

New lower Meade ETX prices save you $50 to $195.

The best-selling **Meade ETX-90PE** Premier Series 3.5" go-to Maksutov with UHTC optical coatings now costs only $699. You save $50!

And the new $999 price for the 5" **Meade ETX-125PE** saves you $195!

It doesn't take a rocket scientist to use a Meade Premier ETX. All you have to do is tell it your zip code. *Level North Technology* automatically levels the optical tube, finds North, sets the time, and moves to two alignment stars. Center the red dot finder on those stars. Then tell your ETX which of the 30,000+ objects in its memory you want to see, and the scope takes you there *automatically.*

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The $69.95 Astro-Tech diagonal is a *2007 Hot Product,* but truth be told, these could *all* be called hot products.

$139.95

$149.95

$69.95

The **Astro-Tech *dielectric* 1.25" star diagonal** was named a *2007 Hot Product* by *Sky & Telescope.*

Like *all* the hot Astro-Tech diagonals, it has advanced 99% reflectivity *46-layer* dielectric coatings on its 1/10th wave BK7 optical glass substrate, plus a brass compression ring eyepiece holder that won't scratch the barrels of your costly eyepieces.

The 2" diagonals have either a 2" barrel for refractors or a threaded ring that connects to a Schmidt-Cassegrain rear cell, plus a separate non-marring compression ring adapter for 1.25" eyepieces.

The 2" *quartz* diagonals provide 1/10th wave peak-to-valley surface accuracy – *even after being coated* – and include a Zygo interferogram as proof of performance.

Here are the prices of the **Astro-Tech** *dielectric* diagonals that we stock:

1.25", *a Hot Product for 2007* **$69.95**
2" with 1.25" adapter **139.95**
2" SCT with 1.25" adapter **149.95**
2" quartz with 1.25" adapter **189.95**
2" quartz SCT w/1.25" adapter **199.95**

Coronado. Still the best buy in solar observing.

$599

For less than cost of some premium eyepieces, the sub-Ångstrom hydrogen alpha filter in the **Coronado PST** (Personal Solar Telescope) lets you see the ever-changing drama of solar flares and prominences growing and subsiding before your eyes. The PST was a 2005 *Hot Product* and it's still a best-seller today.

The PST includes a dedicated 40mm refractor, built-in solar filter, a safe built-in Sun finder, and a 20x eyepiece.

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Quick! What's the best-known name in eyepieces? You guessed it . . . *TeleVue.*

If you're not seeing as much through your telescope as you expected, you may not need a new scope. You may just need a new eyepiece. TeleVue eyepieces let *you* see everything your scope sees. Astronomers have sworn by no-compromiseTeleVue eyepieces since 1980. If you haven't experienced the TeleVue difference by now, isn't it time you let TeleVue open your eyes? Here are the TeleVue eyepieces we stock:

Plössl, 50° field, 1.25" – 8mm, 11mm, or 15mm **$85.00**
20mm or 25mm Plössl, 50° field, 1.25" **99.00**
32mm (50° field) or 40mm (43° field) Plössl, 1.25" **118.00**
55mm Plössl, 50° field, 2" **235.00**
8-24mm long eye relief clickstop Dioptrx zoom, 55° to 40° field, 1.25" **240.00**
3-6mm Nagler zoom with clickstops, 50° field, 1.25" **385.00**
2-4mm Nagler zoom with clickstops, 50° field, 1.25" **395.00**
2.5mm Nagler Type 6, 82° field, 1.25" **290.00**
3.5mm Nagler Type 6, 82° field, 1.25" **290.00**
5mm Nagler Type 6, 82° field, 1.25" **290.00**
7mm Nagler, 82° field, 1.25" **190.00**
7mm Nagler Type 6, 82° field, 1.25" **290.00**
9mm Nagler Type 6, 82° field, 1.25" **290.00**
11mm Nagler Type 6, 82° field, 1.25" **290.00**
12mm Nagler Type 4, 82° field, fits both 1.25" and 2" **365.00**
13mm Nagler Type 6, 82° field, 1.25" **290.00**
16mm Nagler Type 5, 82° field, 1.25" **330.00**
17mm Nagler Type 4, 82° field, 2" **395.00**
20mm Nagler Type 5, 82° field, 2" **450.00**
22mm Nagler Type 4, 82° field, 2" **480.00**
26mm Nagler Type 5, 82° field, 2" **600.00**
31mm Nagler Type 5, 82° field, 2" **640.00**
15mm Panoptic, 68° field, 1.25" **215.00**
19mm Panoptic, 68° field, 1.25" **245.00**
22mm Panoptic, 68° field, fits both 1.25" and 2" **285.00**
24mm Panoptic, 68° field, 1.25" **310.00**
27mm Panoptic, 68° field, 2" **345.00**
35mm Panoptic, 68° field, 2" **380.00**
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Meade 8" f/10 LX200R **$2699** *freight paid*

"Ritchey-Chrétien-like" Meade performance . . . for only a fraction the cost of a true R-C.

Sky & Telescope said Meade's RCX400 f/8 catadioptric "does indeed perform like a Ritchey-Chrétien." And *Astronomy* said it "delivers Ritchey-Chrétien-like performance at a fraction the cost."

A **Meade LX200R** catadioptric scope uses an f/10 version of those same RCX400 f/8 optics (and a few less bells and whistles) to make "Ritchey-Chrétien-like" performance affordable for just about everyone.

Here are the *freight-paid* prices on the Meade LX200R f/10 go-to catadioptrics:

8" LX200R, tripod, UHTC optics **$2699**
10" LX200R, tripod, UHTC optics **3699**
12" LX200R, tripod, UHTC optics **4699**
14" LX200R, tripod, UHTC optics **6499**
16" LX200R, no tripod, w/UHTC **11,999**
16" LX200R, tripod, w/UHTC **12,999**
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Why pay thousands more for the flat field of a true Ritchey-Chrétien reflector optical tube only – and still have to pay for a mount? Meade LX200R catadioptrics with "Ritchey-Chrétien-like" optics and a full go-to mount start at only $2699!

The hot Celestron Sky Scout. In stock.

$399

One of the hardest gifts to find last December was the **Celestron SkyScout**. This spring, this *Hot Product for 2007* is still selling like there's no tomorrow, but we have it in stock for you today.

This GPS-based non-magnifying handheld personal planetarium locates and identifies the more than 6,000 celestial objects visible to your unaided eye. Earbuds tell you their stories, or you can read the scrolling 5-line text/graphics display. SkyScout makes the night sky as familiar to you as your own back yard. Your whole family will love it.

In 1979, a coffee cost 25¢ and a Celestron 8 cost $1295. Today, $1399 buys an even better *go-to* Celestron 8.

Celestron NexStar 5SE 5" Schmidt-Cassegrain **$799**

As for the price of coffee, you practically have to mortgage your house to buy a cup at Starbucks these days.

A C8 that was state-of-the-art in 1979 would cost $3667.08 in today's inflated dollars – but wouldn't have a *SkyAlign* go-to computer, multicoatings, a DC drive, or a Plössl eyepiece like today's $1399 **Celestron NexStar 8 SE.**

But it *would* still have Celestron's superb Schmidt-Cassegrain optics. That's one important benefit that hasn't changed over the years.

Unlike coffee and gasoline and all the other necessities of life, the cost of a Celestron has actually *deflated* over the years. You get more telescope, but you pay less money. That's because many of the features of today's **NexStar SE** scopes were unavailable at *any* price only a few short years ago. For example, the no-guesswork *SkyAlign* go-to computer – a *Sky & Telescope Hot Product for 2006* – automatically finds sky objects to make astronomy as easy as 1-2-3. And Starbright XLT multicoatings give you brighter images and higher contrast.

The **Celestron NexStar SE** telescopes. Great values? *Yes!* Here are the models we stock:

NexStar 4 SE, 4" Maksutov **$599**
NexStar 5 SE, 5" Schmidt **799**
NexStar 6 SE, 6" Schmidt **999**
NexStar 8 SE, 8" Schmidt **1399**

The new Celestron eyepieces are super values.

Compare the prices of these new 70° wide field **Celestron Ultima LX** and 82° ultra-wide field **Celeston Axiom LX** eyepieces with other premium 70° and 82° field eyepieces. The Celestrons are clearly the best values. Here are prices of the Celestron Ultima LX and Axiom LX eyepieces:

Ultima LX, 70° field, fits both 1.25" and 2" – 5, 8, 13, or 17mm **$149.00**
Ultima LX, 70° field, 2" – 22 or 32mm **199.00**
Axiom LX, 82° field, 1.25" – 7, 10, or 15mm **179.00**
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An historic sight

A RAINBOW OF COLORS greeted observers as Comet C/2006 P1 (McNaught) moved into a darker sky. This January 20 image from Hunter Valley in New South Wales shows a dust tail more than 20° high and 30° wide. MIKE SALWAY

The Great Comet of 2007

Observers around the world got spectacular views of Comet C/2006 P1 (McNaught) — the brightest comet in 42 years. /// BY RICHARD TALCOTT

In 1965, the Beatles ruled popular music, while *The Sound of Music* ruled the Oscars. That same year, a bright comet named Ikeya-Seki grazed the Sun and became one of the grandest sights backyard observers had ever seen.

In the 42 years since then, two of the Beatles have died, and *The Sound of Music* has moved onto the "classic" shelves at Blockbuster. But, for comet watchers, Ikeya-Seki remained the gold standard. Other comets — West, Hyakutake, and Hale-Bopp top the list — came and went. All were impressive, but no comet equaled the brilliance of Ikeya-Seki.

Until January 2007. That's when Comet C/2006 P1 (McNaught) burst on the scene and left an indelible impression on everyone who saw it. Sadly, from the Northern Hemisphere, that didn't include many people. The comet hung low in the early evening sky

LARS AND CASPER CHRISTIANSEN

THE PRE-PERIHELION VIEW of Comet McNaught from the Northern Hemisphere wasn't too shabby either. It appeared low in the southwest from Greenland shortly after the Sun set January 10.

MULTIPLE DUST SPIKES pierced the horizon for Northern Hemisphere observers January 19. This view from the slopes of Hawaii's Mauna Loa shows 8 to 10 spikes from the tail of McNaught, whose head lies hidden well below the horizon. STEPHEN J. O'MEARA

during January's second week. Despite shining brighter than magnitude 0, the competing glow of twilight lessened the comet's visual impact.

Once Comet C/2006 P1 rounded the Sun January 12, it brightened further and headed south rapidly. For the next couple of weeks, it rivaled Venus — normally the brightest point of light in the sky — and sported a fan-shaped dust tail that spanned 30° or more. Virtually anyone in the Southern Hemisphere who stepped outside after sunset and looked to the west saw the magnificent sight, the likes of which most had never seen before — and, quite possibly, never will again.

A slow start

It didn't start out this way. Scottish-born astronomer Robert McNaught first spotted the comet August 7, 2006, on images he was taking as part of a search for near-Earth objects at Siding Spring Observatory in Australia. The object appeared as a 17th-magnitude fuzzball and showed no indication of its future brightness.

The International Astronomical Union named the comet C/2006 P1 (McNaught) because it was the first non-periodic comet discovered in August 2006. (Although many people refer to it simply as "Comet McNaught," its "C/2006 P1" designation sets this comet apart from the more than 30 others Robert McNaught has discovered.)

The comet didn't do much for several months. It hovered around 12th magnitude in October and 10th magnitude in November, by which time it was approaching close enough to the Sun that few people were looking. The first hint that something special might be in store came in the second half of December, when the comet started to brighten explosively and became visible to observers without optical aid. The timing meant monthly magazines, like *Astronomy*, weren't able to get the word out except through their web sites.

Comet McNaught's brightness surge surprised astronomers because it appears to be a "fresh" comet, one making its first trip through the inner solar system from

EVEN CITY LIGHTS couldn't stop the comet's impressive show. Here, McNaught gleams above the lights of Launceston, Tasmania, the evening of January 21. MARTIN GEORGE

COMET McNAUGHT ENHANCES this twilight shot taken from Dunedin, New Zealand, and showing Green Island in the foreground. The twilight's colors stem in part from smoke drifting over from Australian bush fires. DAVE CURTIS

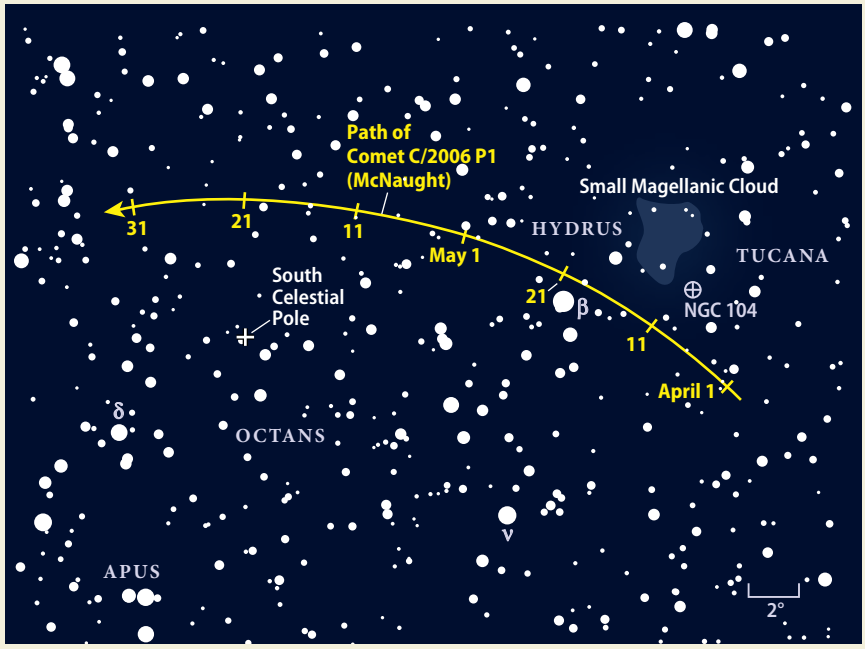
the distant Oort Cloud. Normally, such comets, with a high percentage of volatiles, flare up at large distances from the Sun.

Volatile ices, such as carbon dioxide and carbon monoxide, sublimate (turn directly from solid into gas) at lower temperatures than does water ice. So fresh comets tend to brighten relatively far from the Sun, when their volatile ices sublimate and release lots of gas and dust. As the supply of these ices dwindles, the comet's brightness levels off. That's what happened in the mid-1970s to Comet Kohoutek, whose enormous hype never panned out.

A splendid surprise

That disappointment is why expectations didn't go through the roof until after the new year dawned. Observations during bright twilight showed the comet growing brighter. Northern Hemisphere observers braved the evening chill to glimpse the comet low in the southwestern sky. It was obvious to the naked eyes and stunning through binoculars.

Richard Talcott *is a senior editor of* Astronomy. *He viewed the Great Comet of 2007 low in evening twilight January 9 and 10.*



CATCH THE COMET'S LAST GASPS

COMET McNAUGHT lies deep in the southern sky during April and May, passing by a few bright deep-sky objects. *ASTRONOMY:* ROEN KELLY

Although the great show is now over, southern observers have an opportunity to get a final look at McNaught — the comet against which all other 21st-century comets will be measured. If predictions hold true, the comet will have faded to 10th magnitude by early April and be pushing 13th magnitude in May.

The comet lies far enough south during this period that it remains circumpolar and visible all night from most of the Southern Hemisphere. It even passes by two of the southern sky's greatest deep-sky treasures — the Small Magellanic Cloud (SMC) and its neighboring globular cluster, NGC 104 (47 Tucanae) — creating two wonderful photo opportunities.

McNaught begins April in the constellation Tucana. During April's second week, it skims just 2° from NGC 104, the second-brightest globular cluster in the sky, and then passes equally close to the SMC, a satellite galaxy to the Milky Way. Between April 18 and 22, the 3rd-magnitude star Beta (β) Hydri serves as a bright guide barely 1° from the comet.

During May, the fading comet comes within 5° of the South Celestial Pole. By then, it lies halfway to Jupiter's orbit and no longer will be churning out much dust. It should look like a faint fuzzball, not much different in appearance from what Robert McNaught saw when he discovered the comet last August, although perhaps nearly 100 times brighter. — *R. T.*

You didn't even have to search for it. Lars Christiansen and his son, Casper, had a typical experience. On January 7, Lars wrote from Nuuk, Greenland: "Today my son discovered something unusual in the sky. We managed to get our camera equipment and took some shots of the phenomenon. Is it a comet?" In Greenland, as elsewhere in the Northern Hemisphere, the media didn't have much chance to get the word out.

The same can't be said for those south of the equator. As the comet neared its closest point to the Sun (called perihelion), it continued to brighten. Most astronomers thought it would be off-limits to all but space-based solar observatories at its January 12 perihelion — when it came within 16 million miles (26 million kilometers) and 7° of the Sun. They were wrong.

Comet McNaught grew so bright, observers spied it during broad daylight. Those in the Southern Hemisphere knew what was coming, and they weren't disappointed. As the comet pulled away from the Sun, it challenged Venus as the brightest evening object. It showed up easily even under light-polluted skies — you couldn't miss it if you tried.

THE COMET SINKS toward Montevideo Bay in Uruguay January 19. Hundreds of observers came to the harbor to marvel at the brightest comet since 1965. RODOLFO PÉREZ

The comet also sprouted a dazzlingly complex tail. The multi-component dust tail climbed some 20° high and stretched at least 30° along the horizon. Although McNaught's nucleus lay well below the horizon for Northern Hemisphere observers, parts of the tail poked above the horizon. Stunned northern observers likened the spikes of dusty light to a picket fence.

Experienced observers used the comet to entice novices to the joys of skygazing. Perry Vlahos of the Astronomical Society of Victoria in Australia was flying home to Melbourne from Perth when he looked out the plane's window: "And there was McNaught above the cloud line, with the Sun below — simply stunning."

Vlahos estimated the comet's brightness at magnitude –4, with a tail shooting 5° straight up and then curving north and fanning out. He soon had the flight attendants, the pilots, and most of the passengers staring at the spectacle, which only improved as darkness descended. "Excitement galore, to say the least. The whole plane was almost dangerously listing to one side."

Comet McNaught had 2 weeks of unsurpassed glory. Then, as all things must, it began to fade. By the end of January, it dimmed to 2nd magnitude — still decent, but far less prominent — and found itself in a losing battle with a nearly Full Moon. By late February, it was heading toward binocular territory, and now it's in the realm of telescopes (see "Catch the comet's last gasps," page 58).

Luckily, the memories will have far more staying power. Rodolfo Pérez of Montevideo, Uruguay, remembers a previous visitor. "When I was 13 years old, my father came one night saying, 'Wake up, Rodolfo, you have to see this!' The sight of Ikeya-Seki on that night was a memorable one, and I thought for all these years it could not be beaten. But I have now seen McNaught, and I still can't decide which one was the best."

► **LIKE A DAGGER** poised to strike Earth, Comet McNaught's brilliant head and long dust tail posed for Australian observers January 19. MIKE SALWAY

COMET McNAUGHT lay in the southern sky January 19, 2007, but its multi-component dust tail appeared above the western horizon after sunset. This image shows the view from Colorado just after twilight ended, when the comet's head was 20° below the horizon.

JIMMY WESTLAKE

A tail of two

Like the character in Al Capp's classic comic strip, *Li'l Abner*, I couldn't seem to get out from under the clouds. I saw the best comet in decades, C/2006 P1 (McNaught), only once — from a plane at 41,000 feet. Like many others north of the equator, I enjoyed the comet vicariously, through the images of more-favored southern observers.

But to me, the most arresting images were taken in mid-January from more northern climes. These pictures showed bright rays of light hovering, ghost-like, above the southwestern horizon after evening twilight. I immediately felt I had seen these images before.

I had. They were from a book I treasured as a child, Sir Patrick Moore's *A Picture History of Astronomy*, published in 1961. Among the pictures of famous comets was an engraving of a spectacular object seen in 1744. Identified as "de Chéseaux's Comet," the engraving showed a spectacle of six tails radiating from an unseen nucleus in the predawn skies over Europe. Astronomers have seen many comets approach the Sun in the two-and-a-half centuries since de Chéseaux's Comet appeared, but none of them ever displayed the characteristics of that comet — until now.

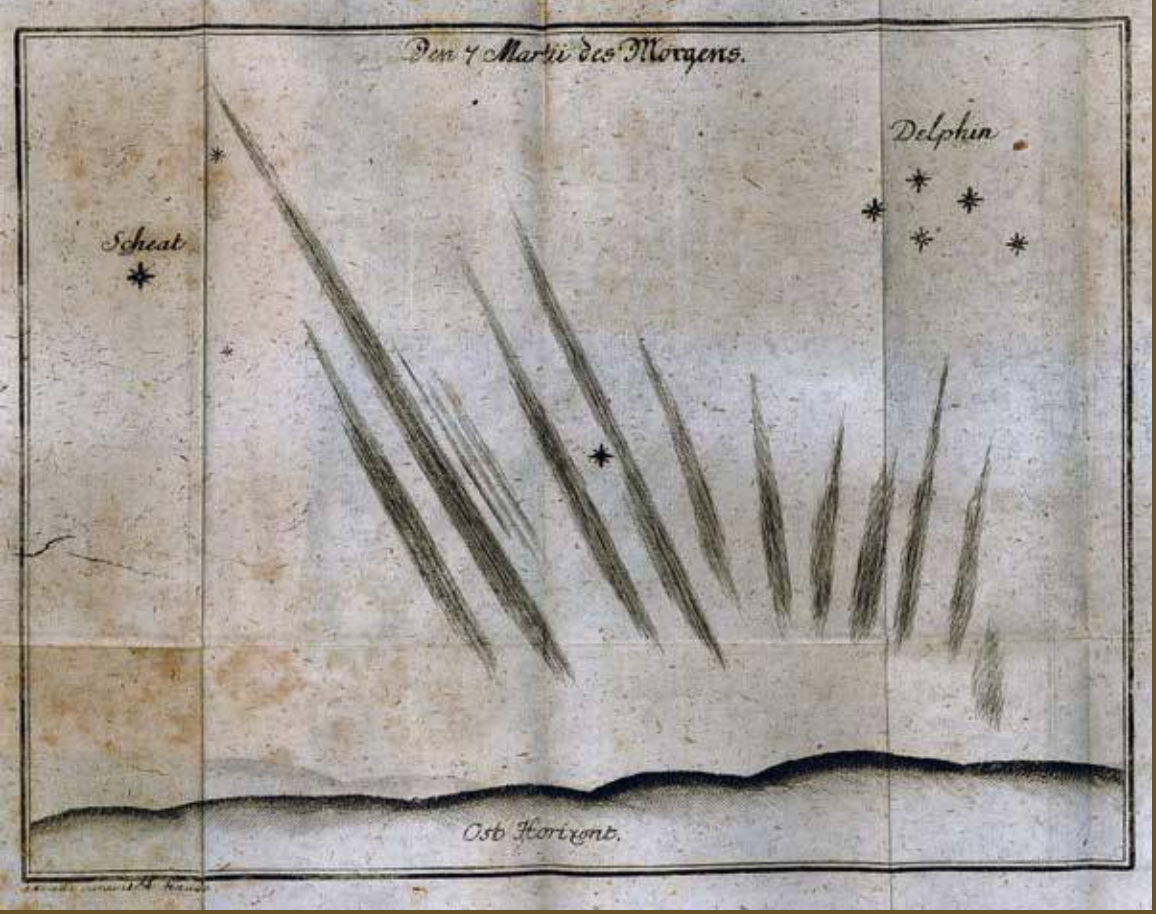
The Great Comet of 1744 — officially designated C/1743 X1 (Klinkenberg-de Chéseaux) — bears no physical relationship to Comet McNaught. Nevertheless, the two share remarkably similar observational histories and orbital properties.

Jean-Philippe Loys de Chéseaux was a wealthy Swiss landowner and astronomer who chanced across a comet December 13, 1743. Although Dutch astronomer Dirk Klinkenberg independently discovered the comet 4 nights earlier, de Chéseaux's rigorous observations allowed him to determine the orbit. C/1743 X1 turned out to have a parabolic orbit that brought the comet within 21 million miles (33 million kilometers) of the Sun at perihelion March 1, 1744. The orbit also inclined steeply (47°) to the ecliptic.

The comet brightened over the next several weeks, and by early February 1744, its glow rivaled that of the star Sirius. It then sported a curved tail some 15° long. C/1743 X1 followed a path that took it "over the top" of the Sun, and by February's close, it was seen with the naked eye just 6 minutes before sunrise. On the 28th, observers glimpsed it in broad daylight some 12° from the Sun.

During the next week, the comet slipped below the horizon. Then, on the mornings of March 7 and 8, de Chéseaux reported a wondrous spectacle: With the comet's head nearly 20° below the horizon, six magnificent tails glowed above the eastern skyline. Several observers confirmed this observation.

Geoff Chester *runs the Public Affairs Office at the U.S. Naval Observatory.*



DE CHÉSEAUX'S COMET also displayed a multi-component tail, which appeared in the eastern sky before sunrise. This copperplate engraving records a dozen discrete spikes as they appeared from Berlin before morning twilight began March 7, 1744.
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comets

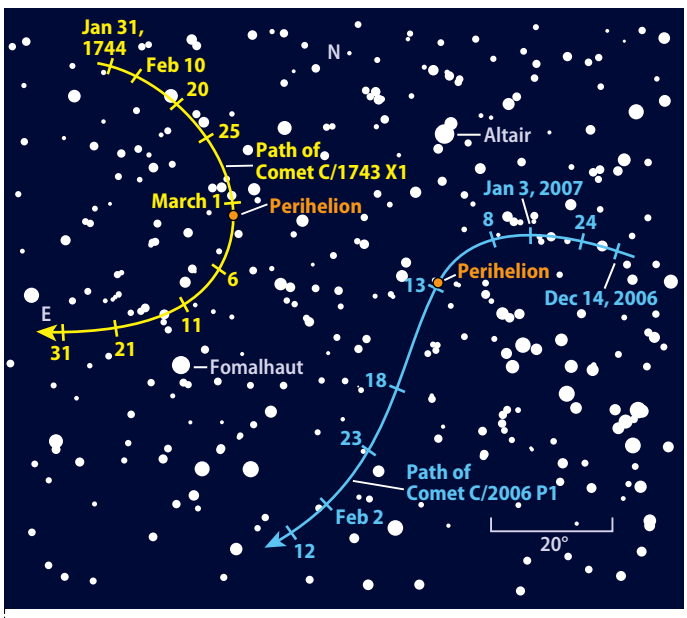
Comet McNaught's multi-spiked tail bore a striking resemblance to that of 1744's great comet. /// BY GEOFF CHESTER

Comet McNaught's orbit shares many traits with that of de Chéseaux's. It is also parabolic (or nearly so), and has a close perihelion distance of 16 million miles (26 million km) coupled with a high inclination (77°). It, too, became spectacularly bright near perihelion and was glimpsed in daylight. It also moved over the top of the Sun on its way to perihelion, then plunged from view for northern observers.

A quick look at the two comets' orbital paths (right) shows they were near mirror images of each other. Although they reached perihelion on opposite sides of the Sun, both came in from the north, made a hard turn around perihelion, and then raced south. Observers saw C/1743 X1 before dawn and C/2006 P1 after dusk.

Both comets shed prodigious amounts of dust as they whipped around the Sun at perihelion. Most likely, this dust was ejected in a series of bursts, perhaps tied to the rotation periods of the respective nuclei. Solar radiation pressure then elongated these dust clouds into streamers.

In both cases, our perspective from Earth favored the forward scattering of sunlight from the dust grains as they slowly spread out from their points of origin. Such precise geometric alignments among the Sun, Earth, and a comet don't happen often — just twice that we know of — but the results are truly spectacular.



A SKY MAP SHOWS why Comet McNaught appeared strikingly similar to Comet Klinkenberg-de Chéseaux: The two orbits mirrored each other. *ASTRONOMY*: ROEN KELLY

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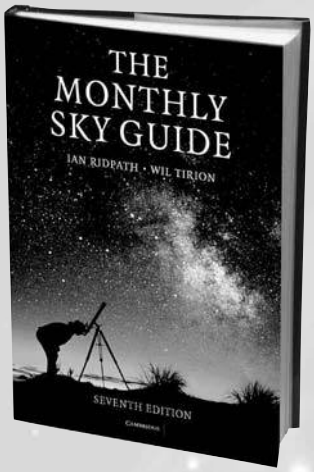

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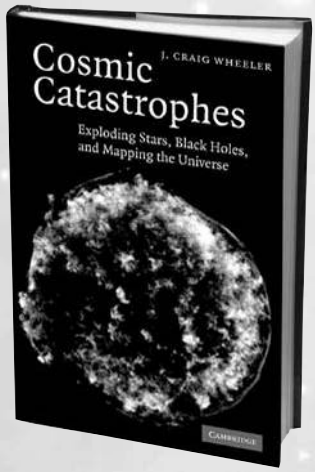

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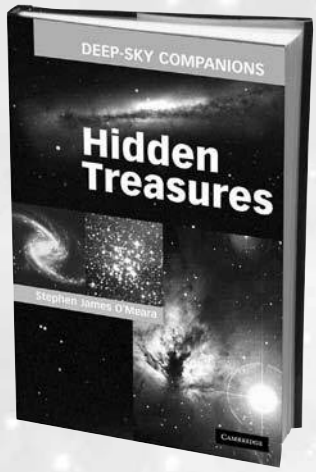

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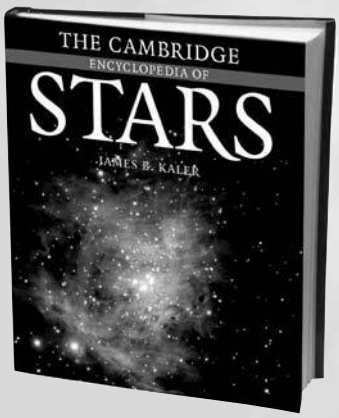

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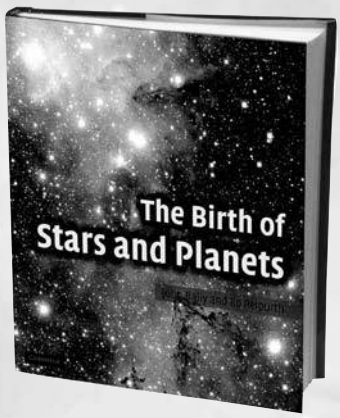

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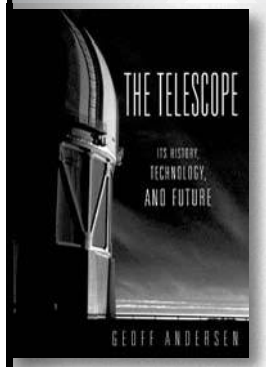

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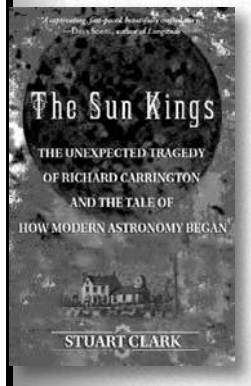

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/// BY RAYMOND SHUBINSKI

All about the Hercules Cluster

The great globular cluster M13 (NGC 6205) is one of the sky's brightest globulars. It's also the one most easily, and most often, viewed by amateur astronomers north of the equator. Under a dark sky, sharp-eyed observers can glimpse the Hercules Cluster with their naked eyes.

Because its light spreads over a small apparent disk, unlike the pinpoint light of a star with the same magnitude, observers often employ averted vision — looking slightly away from a faint object's location — to spot this stellar beehive.

You can find M13 by looking for the "trash can," or Keystone asterism, which lies at the center of the constellation Hercules, the great hero of mythology. Hercules is the Romanized version of the Greek Herakles, an enigmatic fellow best known for his 12 labors, which included flushing out the Augean stables, killing the Nemean lion, and retrieving Cerberus from Hades.

In the Northern Hemisphere, the best views of Hercules come during summer, when it rides high in the sky. Lyra forms most of Hercules' eastern border. You'll find Boötes, Corona Borealis, and Serpens to its west. Ophiuchus lies to the south, and Draco to the north. Magnitude 2.8 Ras Algethi (Alpha [α] Herculis), marks the hero's hand. The four Keystone stars form his body, and the whole figure appears to be kneeling on Draco's head. M13 lies on the western side of the body about 2½° south of Eta (η) on a straight line toward Zeta (ζ), which lies almost 5° away.

M13 through the years

This object must have been seen in ancient times, but it wasn't noted by any of the great astronomers. Had Ptolemy (90–168) seen it, he surely would have mentioned it in his great catalog, *Almagest*.

More than 100 years passed after the telescope's invention before English astronomer Edmond Halley (1656–1742) found M13 in 1714. He noted he could see this patch of light with the naked eye under a dark sky. Halley called it a nebula without stars, clearly demonstrating his telescope's limited resolving power. He also recorded

Pre-photographic observations of the Hercules Cluster

JOHN HERSCHEL, observing through a small telescope near London, sketched the Hercules Cluster in 1833. LINDA HALL LIBRARY OF SCIENCE, ENGINEERING AND TECHNOLOGY

WILLIAM PARSONS, third earl of Rosse, drew the Hercules Cluster as he saw it through his 72-inch reflector in 1861. LINDA HALL LIBRARY OF SCIENCE, ENGINEERING AND TECHNOLOGY

ETIENNE LEOPOLD TROUVELOT recorded the Hercules Cluster in the *Annals of the Observatory of Harvard College* in 1876. LINDA HALL LIBRARY OF SCIENCE, ENGINEERING AND TECHNOLOGY

GLOBULAR CLUSTER M13 in Hercules, the Hercules Cluster, is a favorite target for Northern Hemisphere observers and imagers. Through small telescopes, M13 gives the appearance of a pile of spilled salt. Larger telescopes will resolve this globular's stars. You can see this magnitude 5.8 object with your naked eyes from a dark observing site. TOM BUSH AND JOHN FOX/ADAM BLOCK/NOAO/AURA/NSF

this nebula as being closer to the star Zeta Herculis than Eta. Just the opposite is true. Later observers note this as a printing error.

Fifty years after M13's discovery, French comet-hunter Charles Messier (1730–1817) also observed this object and made it number 13 in his now famous catalog. Strangely, Messier also states M13 "is a nebula which I am sure contains no star." Even taking into account telescope quality and size, it's surprising Messier was not able to resolve this cluster. The cluster's resolution as stars was left to music-master-turned-astronomer William Herschel (1738–1822).

Raymond Shubinski *is the executive director of Science City/Attractions in Kansas City, Missouri.*

On a spring night in 1781, Herschel discovered a fuzzy object, which he first thought was a comet. That object turned out to be a major planet — Uranus. Using a small backyard telescope, Herschel had doubled the size of the solar system.

With his newfound fame (and fortune), Herschel devoted himself entirely to observing. Later, he built two large telescopes, one with a 20-foot focal length and an 18.7-inch mirror and the other with a 40-foot focal length containing a 49.5-inch mirror. The 40-foot telescope proved to be a monster to use, and Herschel went back time and again to the 20-foot telescope. With this scope, he added thousands of nebulae to his catalogs.

While observing the Hercules Cluster in May 1787, Herschel noted it was a rich and beautiful cluster of stars. Finally, M13 had been resolved. Modern observers have the luxury of better optics and have no problems resolving this cluster through much smaller telescopes.

Telescopic highlight

Today, anyone interested in learning about the sky can choose from a plethora of observing guides (such as *Astronomy*'s *Atlas of the Stars*). Some of the most remarkable descriptions, however, come from 19th-century observers who did not have photography to help them along. Many of these early descriptions are well worth a look,

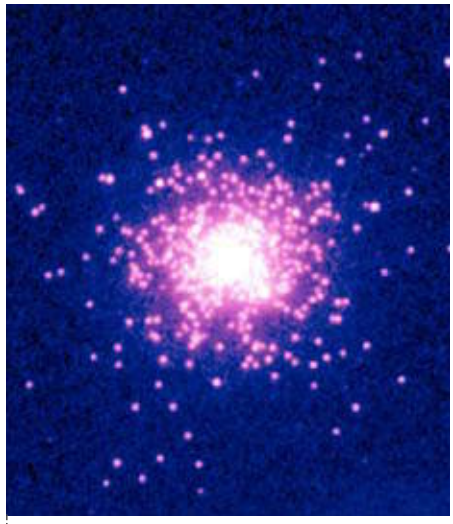
THIS IMAGE of M13 probably was the first published photograph of the object. Welsh amateur astronomer Isaac Roberts (1829–1904) recorded this 60-minute image through his 20-inch reflector May 22, 1887. Roberts' photograph clearly showed the dark lanes referred to by earlier observers. LIBRARY OF MICHAEL E. BAKICH

and they can add to the pleasure of observing M13 today.

One of the best 19th-century sky catalogs was *A Cycle of Celestial Objects*, written by English amateur astronomer William Henry Smyth (1788–1865). Smyth had a lifelong interest in astronomy and dedicated his retirement to following his avocation. The two-volume *Cycle* appeared in 1844. The second volume, *The Bedford Catalogue*, says much about the Hercules Cluster. According to Smyth, the magnificent globular cluster, "or rather ball of stars, [can be found] on the left buttock of Hercules." He goes on to say, "This superb object blazes up in the center, and has numerous outliers around its attenuated disc."

At the start of the 20th century, American astronomy-popularizer Garrett P. Serviss (1851–1929) said this (with typical Victorian flourish): "On a still evening in the early summer, when the Moon is absent and the quiet that the Earth enjoys seems an influence descending from the brooding stars, the spectacle of this sun-cluster in Hercules, viewed with a telescope of not less than five-inches aperture, captivates the mind of the most uncontemplative observer." That's quite a mouthful, but implies the wonder this cluster can bring to even a casual observer.

One of my best views of the Hercules Cluster was through a 10-inch reflector. This scope's long focal length allowed me to use high magnification, and its outstanding contrast provided wonderful detail. With a 10-inch or larger telescope on a night with good seeing, you'll see lots of detail in M13.



AN ULTRAVIOLET LOOK at the Hercules Cluster from the balloon-borne FOCA telescope shows a concentrated center and a few hot, outlying stars. CNRS

A close examination clearly shows the stars are not distributed uniformly within the cluster. M13's central portion appears tightly packed with stars. The outer "halo" of stars thins quickly as the number of associated stars decreases. Also, unlike the bright southern globular Omega Centauri (NGC 5139), which has a uniform distribution of stars, star-poor regions exist in M13. (Try to spot the "propeller," the intersection of three dark lanes near the cluster's center. Most observers also note that, overall, the Hercules Cluster seems to have a rather bluish cast.

Cluster science

Globular clusters like M13 are more than just a treat for observers. In the mid-19th century, English physicist William Huggins (1824–1910) was doing pioneering work in spectroscopy to determine the physical nature of stars in globular clusters. Because of Huggins, and other astronomers, today we know M13 — and all other globulars — are composed of ancient stars useful in deciphering the story of galactic evolution.

Our Sun lies in a barred spiral galaxy. This picture of our home turf is recent and was difficult to obtain. Remember, we live on a planet buried within the Milky Way, and we cannot view our galaxy from afar. As astronomers studied the stars of the Milky Way, two clear divisions became apparent. Most of the stars in our local area, within the spiral arms, have compositions rich in metals (elements heavier than hydrogen and helium). Stars like the Sun result from generations of enrichment by

hot, fast-burning stars. When these stars explode, they spread heavy elements into the interstellar medium. This enriches the next generation of stars. Stars such as the Sun are called Population I stars.

When astronomers examine the stars of the Hercules Cluster or any other globular cluster, they find Extreme Population II stars. These stars are poor in heavy elements. Normal Population II stars, which are slightly richer in metals, inhabit the Milky Way's central bulge. Different types of stars indicate globular clusters formed in our galaxy's first days. Stars in M13 and other globulars are approximately 12 billion years old. Their age provides a lower limit on the Milky Way's age.

Globular clusters also put the cap on the solar system's location within our galaxy. For thousands of years, humans assumed Earth was not just the center around which all celestial bodies revolved, but the very center of creation itself. It took the likes of 16th- and 17th-century greats like Copernicus and Galileo to unseat our cozy spot and place Earth in its rightful place with the other planets. When that happened, however, in the minds of almost all astronomers, the Sun simply replaced Earth at the center of the universe.

In the late-18th century, Herschel began his famous star counts to determine the distribution of stars in the universe. He developed a rough shape for our galaxy, but where did the solar system lie within his model? From Herschel's observations, the Sun still held a central location.

By the 20th century, astronomers were using tools to help find distances to objects far beyond the reach of the measuring stick of parallax. (Parallax is the apparent displacement of a celestial object when viewed from two extremes of Earth's orbit.) One of the most useful distance markers is a type of star known as a Cepheid variable.

THE HERCULES CLUSTER looks about the same through the eyes of the Two Micron All Sky Survey as it does to visible-light instruments. The density of stars near the cluster's core is so great that it becomes a bright blur. We see many stars in this image because near-infrared light is particularly useful for identifying old stars, and globular clusters are composed primarily of old stars. 2MASS

Cepheids are pulsating variable stars that have a relationship between their pulsation periods and brightnesses called the Period-Luminosity law. (See illustration below.) Cepheids gave astronomers a way to estimate great distances. American astronomer Edwin P. Hubble (1889–1953) used the Period-Luminosity law to show galaxies exist far beyond the Milky Way.

American astronomer Harlow Shapley (1885–1972), former director of Harvard College Observatory, noticed the vast majority of globular clusters like M13 lie well away from the galactic plane. But how far away? Cepheid variables allowed Shapley to find the distances to such globulars.

He plotted their distribution, making the assumption that these massive balls of stars would orbit the main gravitational force at the galaxy's center. What he found in this study relegated our solar system to the Milky Way's distant suburbs.

The Hercules Cluster has been the focus of other attention as well. From the mid-1950s well into the 1970s, a wave of UFO mania swept the United States. The world had moved into the Space Age. Was it so hard to imagine we weren't alone in the universe? The majority of astronomers rejected the idea of UFOs, but they were fascinated at the possibility of a galaxy teeming with inhabited planets.

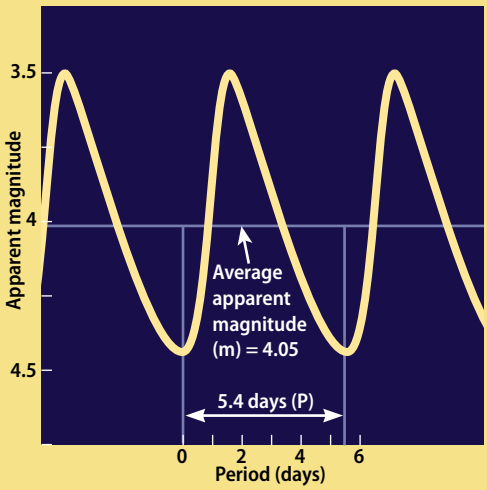
In 1974, the astronomical community decided to instigate interstellar communication. Its attention turned toward M13. Earthly radio transmission has been leaking into space since the 1930s, but no effort had been made to target a specific star or cluster with a message from Earth. In 1974, astronomers at the world's largest radio telescope, the Arecibo dish in Puerto Rico, designed a simple radio transmission representing a greeting card from humanity. As the Hercules Cluster drifted into range, the transmission began, and our calling card left on a 25,000-year journey to M13.

It's hard to imagine a planet in orbit around a giant star in the Hercules Cluster, let alone what its inhabitants, if any, might be. If someone out there ever picks up our incredibly weak signal, it will be another 25,000 years before a reply reaches Earth. Will anyone be here to take the call?

THE HERCULES CLUSTER IN A NUTSHELL

Designations: M13, NGC 6205
Constellation: Hercules
Right ascension (2000.0): 16h42m
Declination (2000.0): 36°28'
Distance: 25,000 light-years
Magnitude: 5.8
Apparent size: 20'
Actual size: 150 light-years
Discovered: 1714, by Edmond Halley

Star distance-finder



CEPHEID VARIABLE STARS form a vital link in the chain of methods used to determine cosmic distances. Delta (δ) Cephei, archetype of the class, changes brightness during a 5.4-day cycle. This period means the star must be about 2,000 times more luminous than our Sun. Comparing the star's luminosity to its observed brightness yields a distance of about 815 light-years when astronomers account for dimming by interstellar dust.
ASTRONOMY: ROEN KELLY

ONLINE EXTRA Meade telescope owners can download a go-to tour of 25 summer globulars at www.astronomy.com/toc.

ASK ASTRO

Astronomy's editors and experts from around the globe answer your questions about the cosmos. This month: the effects of a Moon impact, looking for Vulcanoid asteroids at Mercury, and the definition of "Blue Moon."

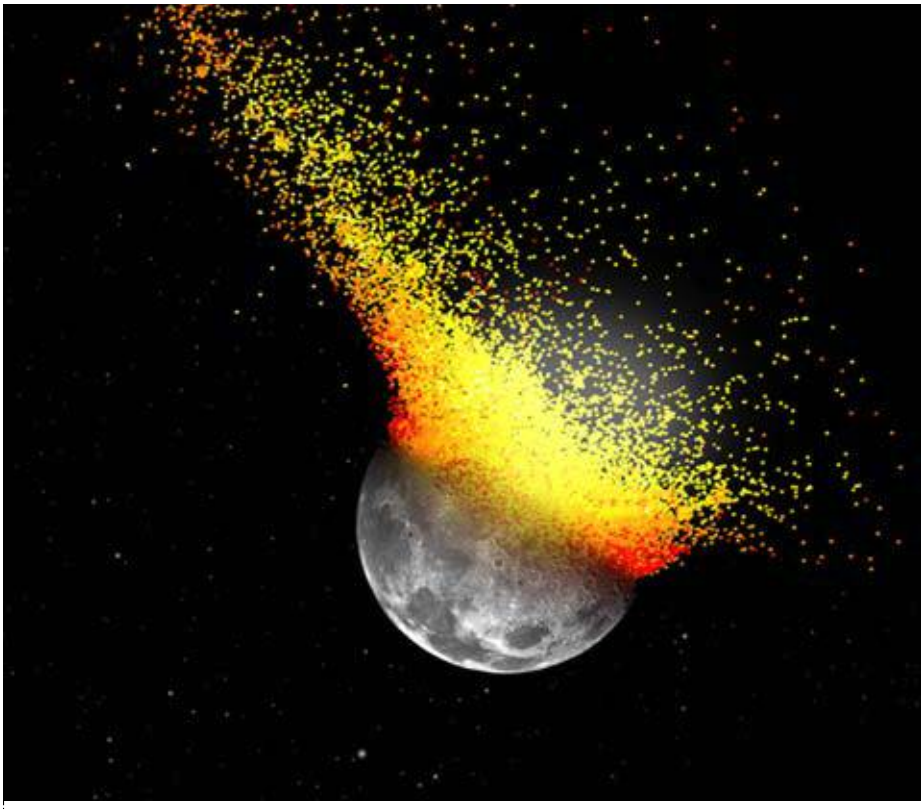
MOON IMPACT

Q: How big of a meteor impact would it take to send the Moon careening into Earth? — **THOMAS KUMIEGA,** MONTVILLE, CONNECTICUT

A: An impact large enough to de-orbit the Moon and send it crashing into Earth would clearly have to be bigger than any impact the Moon has ever endured in its past. Asteroids larger than 62 miles (100 kilometers) in diameter created the Moon's largest impact scars, the Imbrium and South Pole-Aitken basins, almost 4 billion years ago.

Let's imagine a "best-case" scenario whereby the impacting asteroid runs into the Moon head-on, opposite the Moon's motion. Let's further assume the impact occurs at 30,000 mph (61,000 km/h), which is the typical speed of asteroids running into the Earth-Moon system.

An asteroid would have to be about 500 miles (800 km) wide, or a little less than one-fourth of the Moon's mass, to cancel out about 80 percent of the Moon's roughly 2,200 mph (3,600 km/h) orbital speed around Earth. This would leave the Moon falling toward the planet on a trajectory so both objects just barely kiss each other and merge.



DISRUPTING THE MOON wouldn't be an easy task. Calculations of large impacts suggest that any collision big enough to de-orbit the Moon and send it crashing toward Earth would likely destroy the Moon in the process. SOUTHWEST RESEARCH INSTITUTE

In this scenario, the asteroid impacting the Moon would be slightly smaller than Ceres, the largest main-belt asteroid. Fortunately, even the largest near-Earth asteroids capable of impacting the Moon today are 100 times smaller than Ceres, and their impacts would affect the Moon's motion no more than do the gnats that strike your car's windshield as you drive.

But what an impact that would be to witness, at least for a while! For nearly a minute, the asteroid would merge into the Moon's surface. The area of contact between asteroid and Moon would shine as brightly as the Sun. Incandescent mountains of debris would be splashed throughout the Earth-Moon system, and the Moon would be nearly completely disrupted in the process. The remaining molten corpse would begin a week-and-a-half-long death plunge toward Earth before extinguishing all life on our planet. — **DAN DURDA,** SENIOR RESEARCH SCIENTIST, SOUTHWEST RESEARCH INSTITUTE, BOULDER, COLORADO

SEEKING VULCANOIDS

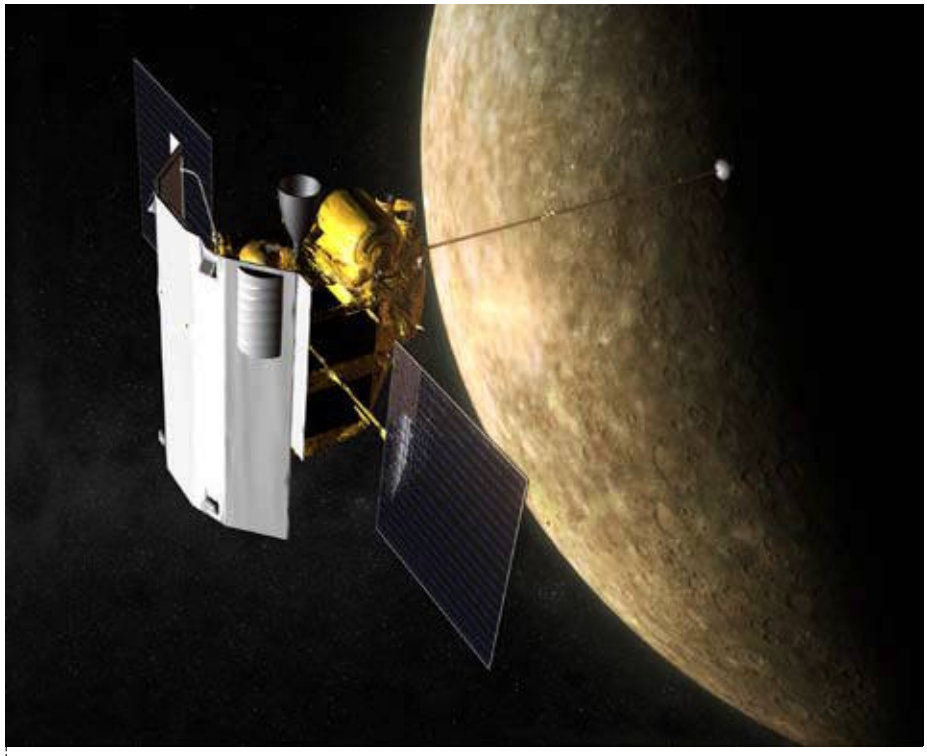
Q: Will the MESSENGER probe be able to spot Vulcanoid asteroids inside Mercury's orbit? — **WENDY KAUPA,** EDWARDS, CALIFORNIA

A: Yes. The MESSENGER mission to Mercury, launched in 2004, will enter orbit around Mercury in 2011. During its yearlong primary mission orbiting Mercury, the spacecraft's seven instruments will study the solar system's smallest planet (not counting Pluto, which was recently demoted to dwarf-planet status). But before it enters orbit, especially starting in early 2008 when MESSENGER first flies past Mercury, the probe may have opportunities to use its wide-angle camera to search for small bodies — moons, comets, and asteroids — in Mercury's vicinity.

The MESSENGER science team will study ways to search for Vulcanoids — asteroid-like planetesimals that may have originally accreted inside Mercury's orbit — and other small bodies near Mercury during the 3 years before MESSENGER's orbital insertion. During this time, the spacecraft will be well-positioned to hunt for the hypothetical Vulcanoids. Such objects would lie in a zone too close to the Sun to be studied from Earth, except with great difficulty (i.e., during daylight with appropriately shielded telescopes, or from satellites designed to study the Sun).

When MESSENGER nears Mercury's orbit, however, it will be able to look for objects that stray much farther from the direction of the Sun, even if they are in small orbits that would have protected them from being readily swept up by Mercury.

If such objects ever existed, many of them may have struck Mercury over the eons, or they may have collided with each other and ground themselves down to dust. But many may yet remain to be discovered. **— CLARK R. CHAPMAN,** SENIOR SCIENTIST, SOUTHWEST RESEARCH INSTITUTE, BOULDER, COLORADO, AND MESSENGER SCIENCE-TEAM MEMBER



NASA/JHUAPL/CARNEGIE INSTITUTION OF WASHINGTON

MESSENGER WILL STUDY Mercury in detail for a year following its arrival at the Sun-scorched inner planet in 2011. As early as 2008, the probe may also search for small bodies near Mercury, including small moons, comets, and the hypothetical Vulcanoid asteroids.

BLUE MOON

Q: What is a "Blue Moon," and does the Moon actually look blue when it happens?

— KELLY SNYDER, BALTIMORE

A: A Blue Moon can be one of several phenomena. In everyday usage, we talk about events that happen "once in a Blue Moon," meaning once in a long while. **Many call a second Full Moon during one calendar month a Blue Moon. The Moon does not appear blue during a Blue Moon.**

An older definition refers to a fourth Full Moon during a season — winter, spring, summer, or fall — instead of the usual three. Of the four Full Moons, however, the third is called the Blue Moon. This way, Full Moons that have traditional names, such as autumn's Harvest Moon, still coincide with the appropriate time of year.

One lunation — the period of time measured from one New Moon to the next New Moon — is approximately 29.5 days. All of the months (except February) are either 30 or 31 days long, which means a pair of Full Moons occurring in a single month happens approximately once every 2½ years.

A Blue Moon is on the agenda in 2007, but when you will see it depends on where you live. People in the United States can witness a second Full Moon during May on the 31st. European, African, Asian, and Australian residents can see the phenomenon June 30, and those living in New Zealand will have to wait until July 30 for their chance.

Regardless of which definition you accept, it's still a relatively long wait until the next Blue Moon: The next pair appears in December 2009, and the next time we see a "long" season will be next spring: May 2008. **— LAURA BAIRD,** ASSOCIATE EDITOR

IN THE KNOW

VULCANOIDS
Theoretical asteroid-like leftover planetesimals that may have originally formed inside Mercury's orbit.

LUNATION
The period of time measured from one New Moon to the next New Moon; approximately 29.5 days.

MESSENGER
NASA's MErcury Surface, Space, ENvironment, GEochemistry, and Ranging (MESSENGER) probe, launched in 2004, will study Mercury beginning in 2011.

COMING NEXT MONTH ...

Do black holes ever disappear? Post your thoughts about this question online at www.astronomy.com/forums.

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Many telescope buyers become discouraged after only a short time. Here's how I evaded that trap. /// **BY MARK M. MARCOTTE**

How to avoid the astronomy blues

Frustration: a feeling of disappointment, exasperation, or weariness caused by aims being thwarted or desires unsatisfied. What frustrates beginners when starting in the hobby of astronomy? I think one of the greatest problems for many stems from not knowing what they really want. Some are seeking knowledge of the universe, while others just want to relax and enjoy the night sky through binoculars or a telescope. Others seek a social activity.

I find people pursuing the latter tend to be the least frustrated, mostly because they know how to get what they want. They just show up for astronomy-club meetings. For the others, however, the journey can be much more confusing and complicated.

Telescope envy

Some beginners think the road starts with a telescope. Telescopes should be considered tools of the trade, but a tool is the means to an end, not the end itself. Those who don't realize this early on tend to be the most frustrated. I was one of those beginners.

I had always had an interest in astronomy. But when a neighbor — who had often seen me and my wife sitting outside, gazing and pointing at the sky — took us to our first astronomy-club stargazing event, we were hooked. We peered through several of the marvelous telescopes that night and enjoyed sights we didn't know were available. We observed distant star clusters, bright nebulae, the belts and bands on Jupiter, and Saturn's unbelievable rings. We also enjoyed the simple pleasure of sitting back in a lawn chair and viewing the sky as a whole. The Milky Way seemed so vivid, it almost cast a shadow.

Although I was in awe of the beauty and grandeur of the night sky, I was drawn especially to the magical workings of the telescopes. I spent the next several days researching telescopes and associated equipment. I was determined to get one of those marvelous tools.

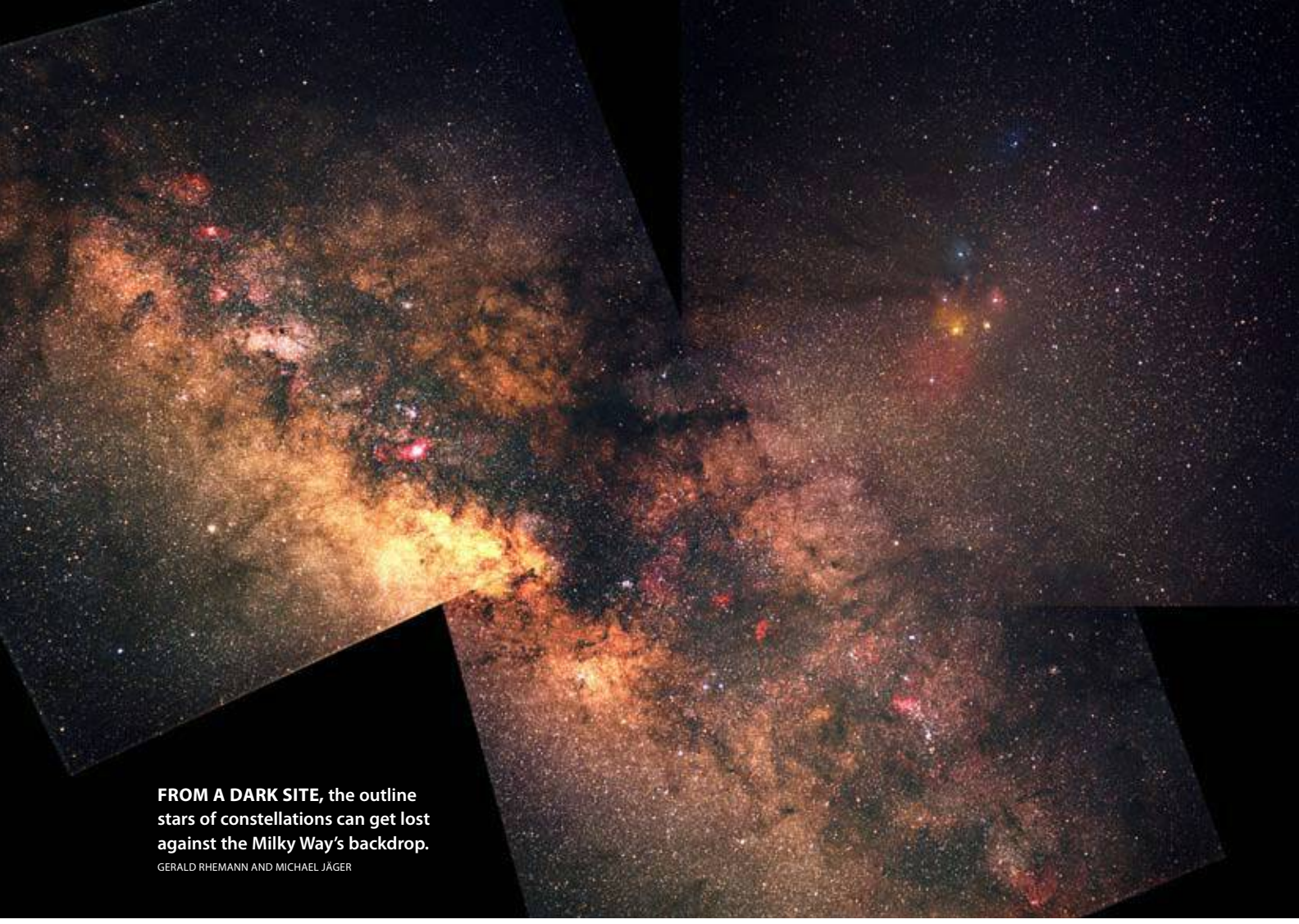
As I searched for "my" telescope, the sheer number of choices quickly overwhelmed me. It was evident that I was going to need help to sort out all of the information. I could hardly wait for the next monthly meeting of the astronomy club so I could pick the brains of all those telescope owners.

Funny thing was, I went to the meeting with the goal of finding the right telescope, but I left with a completely different mindset. My objectives and priorities had changed. I was no longer fixated on a telescope and realized what I really wanted was a clear understanding of the celestial objects I intended to view. This included knowing the location of the constellations and major stars. Little did I know I had traded one frustration for another.

JEFFREY HINES

PICKING A TELESCOPE can be frustrating. To a beginner at a star party like the 1995 Stellafane, there seems to be a mind-numbing profusion of scopes and accessories.

Mark M. Marcotte *is a retired firefighter and amateur astronomer who observes in and around Lubbock, Texas with a variety of scopes.*



FROM A DARK SITE, the outline stars of constellations can get lost against the Milky Way's backdrop.
GERALD RHEMANN AND MICHAEL JÄGER

Identity theft

This new hindrance was a more subtle and less intrusive type, yet it was a frustration. I acquired the essential star charts and books and proceeded to study and memorize until my poor brain yelled "uncle." I tried to stay as basic as possible. But learning alone from a book and then applying that knowledge to the sky introduced new challenges. For example, I had trouble grasping the different sizes and dimensions of celestial objects, and earthly obstructions rendered certain sights invisible.

My wife said I was quite a sight out in the backyard. I had books and charts spread all over the ground. I held a flashlight in one hand and pointed and gestured into the night sky with the other. I moved from one side of the yard to the other to avoid obstacles, all the while carrying on a conversation with myself.

So much depends on the conditions at your observing site that no book or chart is a "one size fits all." I learned to recognize the stars and constellations in conditions of moderate light pollution — which, for most purposes, causes way too much frustration. It's an advantage in this pursuit, however.

After I had learned a fair number of sky highlights, I ventured out to the astronomy club's dark-sky site in hopes of impressing some of the more experienced members. The problem started when I tried to identify the same stars where there was almost no light pollution. I quickly learned that moderate light pollution blocks many of the dimmer stars, thus making it easier to identify the brighter stars that form the constellations' outlines.

Suddenly, a constellation that had only 10 visible stars in the city now appeared with hundreds of stars, making it almost impossible for me to pick out the patterns I had laboriously learned. I spent most of the evening (and several subsequent ones) relearning them.

Say what?

One of my most daunting hurdles — and one I'm still confronting today — was learning the correct pronunciations of star and constellation names. For many people this is no problem, but for the elocution-impaired like myself, these names can leave your tongue tied in a square knot.

For an example, take the three brightest stars in the spring constellation Libra the Scales — Zubenelgenubi, Zubeneschamali, and Zubenelakrab. Believe me, if you can locate these three stars in the night sky and pronounce their names, you will be the coolest person at any star party.

Some frustrations exist in every endeavor, and the hobby of amateur astronomy is no exception. But, in the end, overcoming these struggles yields a wonderful and rewarding experience that will last you a lifetime. So when that feeling of frustration starts creeping in, just remember to slow down, be patient, and don't break anything expensive. A

ONLINE EXTRA Share your frustrations, and we'll include them in an *Astronomy* blog. E-mail mbakich@astronomy.com.

Meade's LightBridge will help you see faint details in distant targets.

/// BY MARK M. MARCOTTE

Deep-sky-object hunter

Like many observers, I have a fondness for Dobsonian-mounted telescopes. Such instruments allow users to use a large aperture — 8 inches and above — that is inexpensive and easy to transport, set up, and operate. That made it a "no-brainer" when I got the opportunity to take Meade's truss-tube Dobsonian, the LightBridge, through its paces.

The LightBridge I tested was the 10-inch deluxe model. Meade offers this scope in four sizes: 8-, 10-, 12-, and 16-inch apertures. All models come in either the standard or deluxe version, except the 16-inch, which comes only in the deluxe model.

Deluxe versions have three upgrades: a steel right-ascension roller-bearing in the base (instead of the standard Teflon guides), a 26mm QX Wide Angle 2" eyepiece (in place of the standard 26mm Series 4000 1.5 Super Plössl), and a four-reticle red-dot viewfinder (in place of the standard red-dot finder). Prices range from around $600 for the deluxe 8-inch model to $2,000 for the deluxe 16-inch model. Standard models each run about $100 less.

The truss variation of the Dobsonian mount makes large telescopes more portable by breaking down their elements into compact packages. But until Meade started mass-producing them, only high-end or homemade Dobs used the truss design. In other words, to find a truss telescope, you either had to build your own or spend major bucks — and wait several months. Finally, a viable option has emerged.

Setup

Meade's LightBridge comes packaged in two large cardboard boxes. One contains the optical-tube assembly (OTA), and the other holds the base. The OTA box may be too much for one small person to handle, but the base's box is easy to deal with.

The base goes together with only a supplied Allen wrench, and assembly is intuitive if you've ever been around a Dobsonian mount. If not, the instructions will guide you through the assembly process.

The OTA comes in two parts, the primary mirror box and the secondary mirror and focuser cage. Three truss assemblies connect these two parts. At first, this seemed a bit unorthodox but, once assembled, proved to be well-designed and solid. I suggest the first time you put the scope together you have an extra person available to help hold things, because a dropped part at this point could ruin your day.

The first thing I noticed about the assembled telescope was how pleasing it is to the eyes. The brushed-aluminum bearings and truss poles, combined with the white and black of the base and OTA, give the telescope a sleek, modern look.

The height of the eyepiece when the scope is pointed toward the zenith is right at 48 inches. This is a comfortable height for the average person seated on a stool.

Operation

As for the LightBridge's mechanics, azimuth tension is adjustable, which allows the user to set the right amount of drag so the telescope turns easily, but with no free movement. This feature works well, especially considering the base rides on roller bearings, which, in other mounts I've used, tend to be either too loose or too tight.

THE CRAYFORD-STYLE focuser accommodates both 2" and 1¼" eyepieces (with an included adapter). A tension adjustment combined with a locking mechanism lets you use heavy eyepieces.

The altitude bearings ride on thick felt strips that provide just the right amount of tension. My first thought was that the strips might wear out quickly, but if you clean the bearings, the felt will last a long time. Besides, felt is easy and inexpensive to replace. The altitude bearings also have a tension feature. This maintained smooth operation when I viewed objects near the horizon, or when using extra-big eyepieces.

If you plan on using something really heavy, like photography equipment, look into an after-market system to counterbalance the scope. Overall, this scope's azimuth and altitude operations are excellent. With little effort, I set the tension for both axes equally, which is the optimum situation for a good Dob mount. In doing so, I was able to follow celestial objects easily with just the slightest pressure on the tube.

The stock Crayford-style 2" focuser has a nice, solid feel. It moved smoothly through its entire range and did not drift

Mark M. Marcotte *is a retired firefighter and amateur astronomer who observes from Lubbock, Texas.*

MEADE'S LIGHTBRIDGE telescope combines a short-focal-length Newtonian reflector with a Dobsonian mount. Because of its modular construction, setup and takedown are easy and make this a portable scope for its size. ALL PHOTOS: *ASTRONOMY*: WILLIAM ZUBACK; STAR CHART: *ASTRONOMY*: RICH TALCOTT AND ROEN KELLY

/// SPECIFICATIONS

10-INCH MEADE LIGHTBRIDGE DOBSONIAN

Type: Dobsonian-mounted Newtonian reflector
Aperture: 10 inches (254mm)
Focal ratio: f/5
Focal length: 1,270mm

DIMENSIONS:
OTA: length = 47" (1,194mm); diameter = 12" (305mm)
Base: height = 18.5" (470mm); diameter = 22" (559mm)
Eyepiece height when scope aimed at zenith: 48" (1,220mm)
Secondary housing weight: 6 lbs. (2.7 kg)
Total truss weight: 2 lbs. (0.9 kg)
OTA primary housing weight: 30 lbs. (13.6 kg)
Assembled mount weight: 27 lbs (12.3 kg)

Also included: Crayford-style 2" focuser with 1¼" adapter, built-in primary-mirror cooling fan
Price: $799

THE 10-INCH LIGHTBRIDGE contains an f/5 primary mirror. Both the primary and secondary mirrors have magnesium-fluoride overcoatings. A battery-powered cooling fan sits under the primary.

THE LIGHTBRIDGE breaks down into four easily handled components: (1) the base, which is a Dobsonian design; (2) the primary-mirror assembly; (3) the support struts; and (4) the secondary-mirror assembly, which also houses the focuser and finder scope.

when stopped. As for the finder scope, Meade went with a common red-dot finder (RDF). Standard LightBridge models come with the plain RDF, but the deluxe models have an RDF with different, interchangeable reticles: a dot, a circle with a dot, crosshairs, and crosshairs with a circle. Reticle brightness is adjustable, which is a real plus.

For the most part, the RDF is a good finder, but I had two problems: Sighting through the finder (up the tube of a Newtonian telescope) is tolerable at low angles, but the higher the angle, the more difficult it becomes. A right-angle finder seems to make more sense for this scope.

The second issue is the RDF needs an Allen wrench to adjust the reticle. This is fine during the day, in a location like your backyard. But at night, miles from civilization, a telescope should not require you to carry any tool smaller than your arm.

CONTACT INFORMATION

Meade Instruments Corporation
6001 Oak Canyon
Irvine, CA 92618
[t] 800.626.3233
[w] www.meade.com

Guan Sheng Optics of Taiwan, which has a reputation for high-quality products, produces the LightBridge's optics. Collimating the primary mirror is a straightforward operation because the primary's adjustment knobs are large and accessible. Secondary-mirror adjustment is more difficult because it requires a Phillips screwdriver. (You can replace the screws with readily available after-market knobs.)

The telescope held collimation well, except when I disassembled the OTA, but this is common for truss Dobs. Meade includes a battery-powered fan for the primary, which is a great time-saver for cooling the mirror after it has been in a hot car.

The truss knobs are captive to their respective parts and will not be lost in the black of night. With a little practice, you'll reassemble this scope in minutes in the field. The assembled base is easy to carry, although it may not fit into a small car's trunk. For short trips, use the back seat.

I found a small problem with ambient light. Remember the LightBridge's beautiful white exterior? Well, Meade extended some of that pretty white exterior into the OTA's interior. At that point, it loses all its beauty and just becomes a good surface for ambient light to launch its annoying intrusions. This telescope needs a light shield for the upper-truss assembly to cut that stray light from entering the eyepiece.

A bridge to the sky

The biggest advantage of this telescope is its portability. The tradeoff for portability is assembly and collimation time, but all truss Dobs require collimation every time they're reassembled. Of course, one thing to consider when getting a truss telescope for its portability is that a disassembled 12-inch scope does not take up much more space than a disassembled 10-inch scope.

Generally speaking, if cost or preference for a smaller size is not the greatest determining factor, I would get nothing smaller than the 12-inch telescope, and I would seriously consider the 16-inch model. After all, the whole idea of the truss Dob is to bring portability to large telescopes.

The bottom line on Meade's LightBridge is that it's a lot of scope for the money. It's a good-looking scope whose optics match any telescopes in this price range. The ease of movement compares to high-end Dobs. The standard models will satisfy beginners, and the deluxe models will fit the bill for intermediate observers. Although the LightBridge is not a competitor of high-end Dobs, Meade has brought a solid, inexpensive truss Dob to the mass market. A

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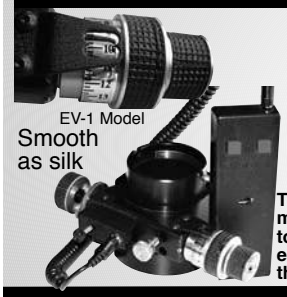

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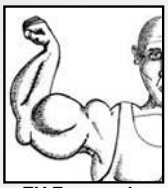

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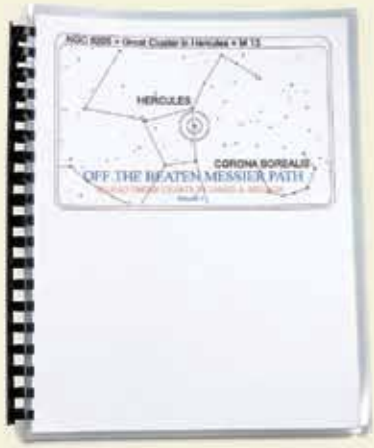

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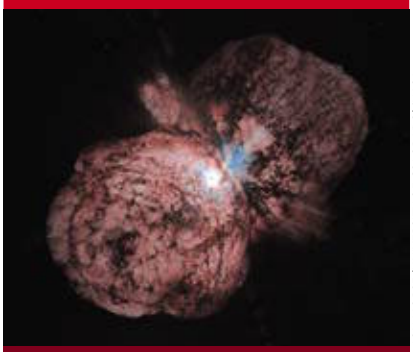

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NGC 3718'S spiral arms beckoned astro-imagers at the University of Arizona's May 2006 camp for advanced observers.

MAY 4
Lecture: "Looking at the surfaces of 'A' stars — and finding the unexpected"
Kaufmann Auditorium, American Museum of Natural History, New York. Deane Peterson of SUNY Stony Brook. 💻 www.aaa.org/aaalecture.htm.

MAY 5–6
Northeast Astronomy Forum (NEAF) and Telescope Show
Rockland Community College, Suffern, New York. *Astronomy* Contributing Editor Stephen James O'Meara will attend. 💻 www.rocklandastronomy.com.

MAY 6
Lecture: "The day the Sun blew up"
Jewish Community Center of San Francisco, San Francisco. Astronomer Sten Odenwald. 💻 www.astronomycafe.net.

MAY 10–13
Frozen Banana Star Party
Munro Park, Powassan, Ontario. ☎ 705.669.7750; ✉ hhealy@simpatico.ca.

MAY 17–20
Central Nevada Star Party
Monte Cristo's Castle, Tonopah, Nevada. 💻 www.tas.astronomynv.org/cnspIII.htm.

MAY 17–20
Cherry Springs Star Party
Cherry Springs State Park, Galeton, Pennsylvania. 💻 www.cherrysprings.org.

MAY 18–19
North Central Region of the Astronomical League Convention
Fargo, North Dakota. ✉ shawn.johnston@gmail.com; 💻 www.fmastronomy.com.

MAY 18–20
Texas Guitars and Stars Fest
Lake Whitney State Park, Whitney, Texas. ☎ 817.656.0901; ✉ distglow@sbcglobal.net.

MAY 25–28
Riverside Telescope Makers Conference (RTMC) Astronomy Expo
Big Bear, California. *Astronomy* Associate Editor Laura Layton will attend. 💻 www.rtmcastronomyexpo.org. A

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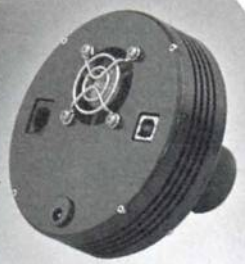

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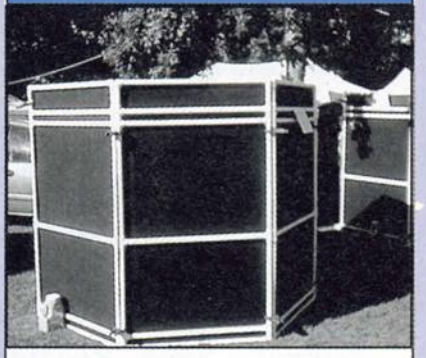

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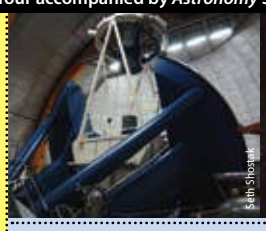

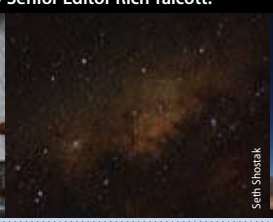

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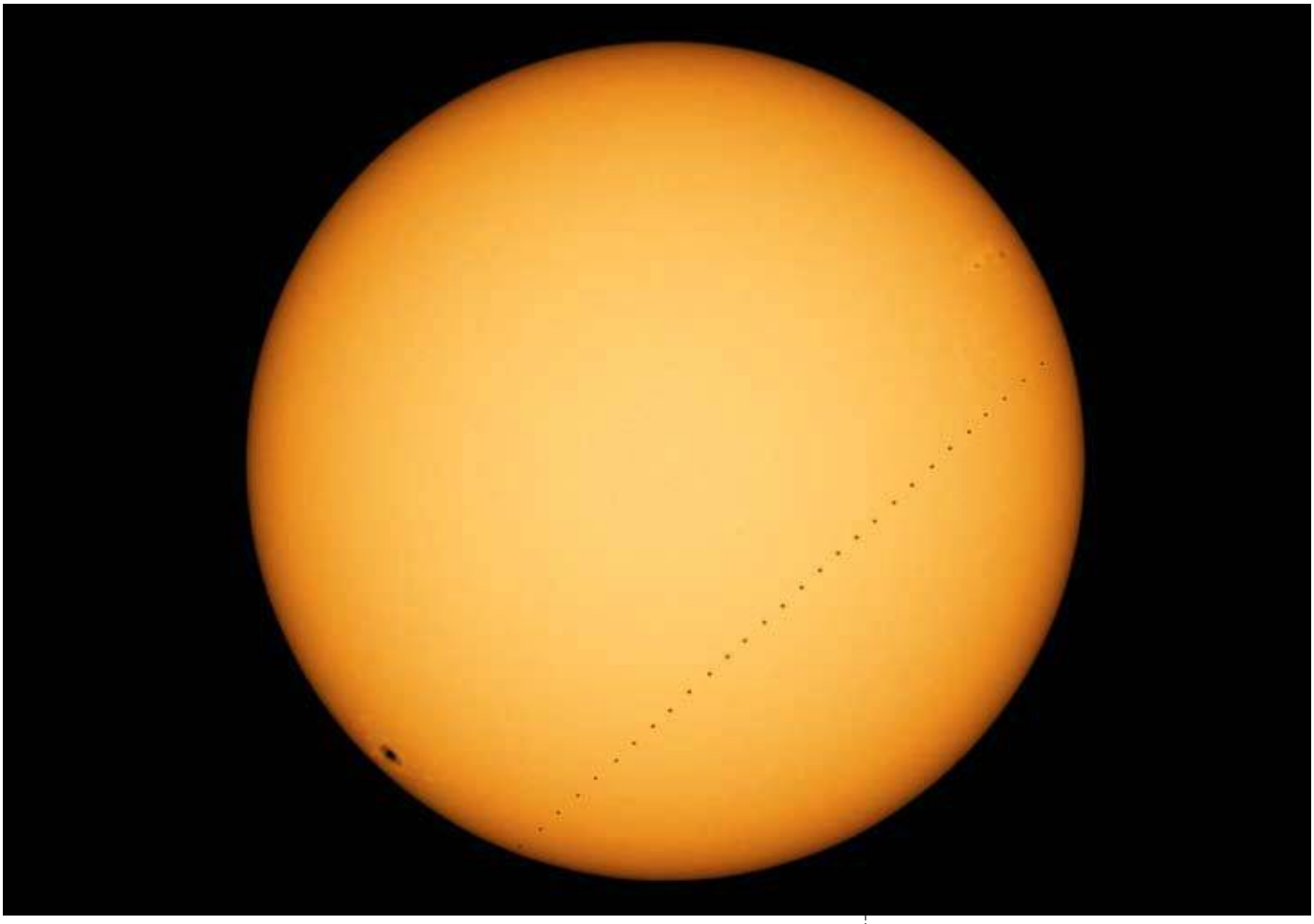
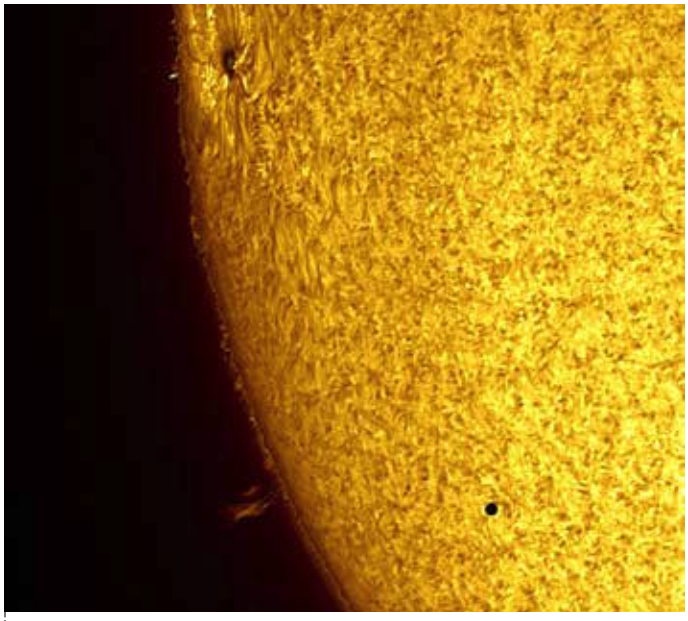


MERCURY TRANSIT (4-inch Takahashi FSQ-106 apochromatic refractor at f/5, Nikon D200 digital SLR, three 1/40-second exposures plus three 1/50-second ones taken at 10-minute intervals, November 8, 2006) /// **BILL HOOD, TORRANCE, CALIFORNIA**

SOLAR CROSSING

Mercury transits the Sun

On November 8, 2006, observers in North and South America, Australia, and parts of Asia witnessed Mercury's last transit for 10 years. A transit occurs when Mercury, which lies closer to the Sun than Earth, passes in front of the Sun from our vantage point. This happens 13 or 14 times each century. Mercury's next solar passage will occur May 9, 2016. Last year's event took nearly 5 hours to complete. Judging by the many excellent images *Astronomy* received, clear skies were abundant across the viewing area. During the transit, Mercury appeared as a black circle, 1/180 the Sun's diameter, silhouetted against the brilliant solar disk.



MERCURY'S TRANSIT looked even better through a Hydrogen-alpha filter. (Double-stacked Coronado SolarMax 90 telescope on a Takahashi NJP Temma 2 mount, Lumenera SKYnyx 2–1 CCD camera, eighty-one 0.0234-second surface exposures combined with seventy-two 0.043-second prominence exposures, taken November 8, 2006, at 1:39:33 CST) /// **PHILLIP JONES, FRISCO, TEXAS**

THE SATURN NEBULA (NGC 7009) in Aquarius was the first object English astronomer William Herschel (1738–1822) put in his catalog of deep-sky objects. (14.5-inch RC Optical Systems Ritchey-Chrétien reflector at f/9, SBIG STL-10XE CCD camera, LRGB image with exposures of 50, 40, 40, and 50 minutes, respectively) /// **DANIEL VERSCHATSE, ANTILHUE OBSERVATORY, CHILE**

REFLECTION NEBULAE Van den Bergh 14 and 15 in Camelopardalis each reflect the light of a 5th-magnitude star. VdB 15 also has a reddish emission component. (6.4-inch Takahashi Epsilon 160 hyperbolic astrograph at f/3.3, SBIG ST-10XME CCD camera, LRGB image with exposures of 50, 30, 30, and 39 minutes, respectively) /// **DEAN SALMAN, TUCSON, ARIZONA**

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Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.

GLOBULAR CLUSTER M80 in Scorpius lies approximately 4.5° northwest of Antares (Alpha [α] Scorpii) in a beautiful star field. (14.5-inch RC Optical Systems Ritchey-Chrétien reflector at f/9, SBIG STL-11000 CCD camera, LRGB image with exposures of 48, 20, 20, and 20 minutes, respectively) /// **DANIEL VERSCHATSE, ANTILHUE OBSERVATORY, CHILE**

SHARPLESS 2–91 appeared on American astronomer Stewart Sharpless' famous list of HII regions. It is, however, a supernova remnant, now classified as G65.3+5.7. (200mm Nikon telephoto lens at f/2, SBIG STL-6303E CCD camera, Astrodon filters, HαRGB image with exposures of 510, 30, 30, and 30 minutes, respectively) /// **PAOLO CANDY, SORIANO NEL CIMINO, ITALY**

EMISSION NEBULAE NGC 3576 (left) and NGC 3603 lie in the southern constellation Carina. Each nebula represents a region of active star formation. (3.2-inch Apogee achromatic refractor at f/5.8, Starlight XPress SXV-H9 CCD camera, LHαRGB image with exposures of 25, 50, 10, 10, and 15 minutes, respectively) /// **MICHAEL SIDONIO, GOOGONG, NEW SOUTH WALES, AUSTRALIA**

STAR CLOUD M24 in Sagittarius shows how "cloudy" our Milky Way is — not with clouds of water droplets, but, instead, with dust and gas clouds. (3-inch Tele Vue 76 apochromatic refractor at f/6.3, SBIG ST-10XME CCD camera, LRGB image with all exposures 15 minutes in length) /// **FRED CALVERT AND ADAM BLOCK/NOAO/AURA/NSF**

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